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TA 02-02
NEDU TR 04-13
April 2004

EFFECTS OF DELAYS AT DEPTH ON DIVER INSPIRED OXYGEN PARTIAL PRESSURES IN SIMULATED LOCKOUTS USING THE MK 25 MOD 2 UBA

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(U) EFFECTS OF DELAYS AT DEPTH ON DIVER-INSPIRED OXYGEN PARTIAL PRESSURES IN SIMULATED LOCKOUTS USING THE MK 25 MOD 2 UBA

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Divers using the MK 25 provided data on partial pressures of oxygen (PO_2) during deep lockout simulations at 60 feet of seawater (fsw), simulations in which delays of 1, 10, and 30 min at depth were manipulated before ascent to 15 fsw. Divers assumed a vertical orientation and maintained a restful state in euthermic water conditions throughout the procedure. Eighty-one of 88 dives were completed without violating PO_2 safety criteria. Two dives in the one-minute delay condition (n = 25) and three dives in the 10 min delay condition (n = 35) resulted in low PO_2 (≤0.16 atmospheres absolute [ATA]), and two dives in the 30 min delay condition (n = 28) resulted in high PO_2 (≥1.70 ATA for more than 10 min). Binary confidence limits for violating PO_2 safety criteria were between 0.003 and 0.320.

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INTRODUCTION

The Advanced SEAL Delivery System (ASDS) is a small, dry submarine capable of supporting a wide range of operational scenarios and depths. It allows U.S. Navy SEALS to leave the host sub and approach targets in an environment that preserves physical readiness. To reduce the likelihood of detecting the ASDS from the surface, U.S. Navy SEALS may have to perform lockout (LO) operations using the MK 25 MOD 2 (MK 25) Underwater Breathing Apparatus (UBA) at depths greater than 20 feet of seawater (fsw). Pursuant to previous testing by Navy Experimental Diving Unit (NEDU) in which it was shown that MK 25 LO procedures could be undertaken from a depth of 50 fsw,[3] the Commodore of Naval Special Warfare Croup THREE (NAVSPECWARGRP3) requested development of MK 25 LO procedures from a depth of 60 fsw.[1,2] Such procedures were designed and tested in NEDU's Ocean Simulation Facility (OSF) to characterize the risks incurred during representative scenarios.

Central nervous system (CNS) oxygen toxicity and hypoxia are the major risks associated with use of the MK 25 UBA in deep LO operations, and only one excursion to any depth greater than 20 fsw is permitted in a 4-hour dive using the MK 25. Diver inspired oxygen partial pressure was monitored throughout the course of each test as a factor governing these risks, and to determine whether the procedures cause divers to exceed O_2 exposure limits. Tested procedures also incorporated preascent delays of 1, 10, or 30 minutes, because U.S. Navy SEALS and support divers indicated that operators locking out from the ASDS may have to delay their ascent to "normal" transit depth of 15 to 20 fsw for as long as 30 minutes.

METHODS

EXPERIMENTAL DESIGN AND ANALYSIS

U.S. Navy and Marine Corps divers experienced in MK 25 operations and trained to conduct free ascents participated in the trials. All divers received additional training in the NEDU test pool to become familiar with the "de-purge" procedure before proceeding to the OSF trials.

The OSF wetpot was configured to support eight divers in euthermic water (75–85 °F). Testing was conducted over a 3 day period from 26 to 28 October 2003. A faulty O_2 fuel cell discovered on the first dive reduced the number of divers to seven per set for the duration of the study. During each evolution, the complex was pressed on air to 57 fsw (60 fsw with a three-fsw offset). Divers then completed a 1, 10, or 30-minute delay at 60 fsw before ascent.

Oxygen partial pressures were recorded throughout all dives. Safety parameters were selected to prevent hypoxia and CNS O_2 toxicity and to avoid exceeding operational excursion limits. Procedures were considered "safe" if inspired oxygen levels from the MK 25 did not fall below 0.16 atmospheres absolute (ATA), increase above 1.7 ATA for 10 minutes, or exceed 2.4 ATA at any time. A dive was aborted if any of these criteria was violated.

EQUIPMENT AND INSTRUMENTATION

Each MK 25 was instrumented with a Teledyne R-10DS O_2 fuel cell positioned in a gas sample block at the base of the inhalation hose. Linear operational calibration of R-10DS fuel cells was obtained from measured voltage outputs flushed at sea level with air (PO_2 = 0.21 atmospheres [ATM]) and 100% O_2 (PO_2 = 1.00 ATM) each day before diving. Data from each diver's O_2 cell was transmitted to the medical deck in real time and recorded as PO_2 in atmospheres by converting outputs of measured fuel cell voltage. Fuel cell data was logged at two-second intervals with a National Instruments LabVIEW (Austin, TX) data acquisition system.

The OSF was equipped with a two-tiered diver platform. The upper level, or highstand, was set at a level approximately three feet below the OSF waterline. Thus, the diver's torso and MK 25 were both above the waterline while he was standing on the highstand. The lower level was approximately six feet below the highstand. Both levels could comfortably accommodate eight divers.

Depth was recorded with a Druck 0–50 psi pressure gauge, and water temperature was obtained with a YSI Incorporated (Yellow Springs, OH) 700 series thermistor.

DATA REDUCTION AND ANALYSIS

Each diver's inspired PO_2 was monitored with a Teledyne R-10DS O_2 fuel cell positioned in a gas sample block at the base of the inhalation hose on each MK 25. Voltage output from each fuel cell was passed by umbilical to a real-time data acquisition system on the OSF Medical Deck, where it was converted to PO_2 in atmospheres and recorded for the diver at midchest depth.

MK 25 PO_2 values remained below 1.0 ATA, hence within the linear calibration range of the R-10DS fuel cells, nearly all the time. Consequently, recorded PO_2 values did not require correction for nonlinearities in fuel cell output versus PO_2 that occur at higher PO_2[5]. Most of the PO_2 values that exceeded 1.0 ATA resulted from an O_2 fuel cell "voltage spike" following a MK 25 O_2 add-valve actuation. Recorded dive profiles were analyzed with software modified from that developed in earlier work.[6] Recorded PO_2 values were smoothed with a 25-point moving quadratic convolute. Smoothed dive profiles are given in Appendix A. Summary information about each profile was compiled from these smoothed profiles and is presented in Appendix B.

The summary information for each profile was compiled with respect to depth-related dive events; Leave Surface (LS), Reach Bottom (RS), Leave Bottom (LB), and Reach First Stop (FS). The times at which each of these events occurred in a profile; TLS, TRS, TLB, and TFS, respectively; were determined from recorded depths smoothed with an 11-point moving quadratic convolute. TLS was determined as the time when the smoothed depth first exceeded the mean smoothed depth of the first 30 seconds of the recorded profile plus one fsw, and thereafter failed to fall shallower than five fsw. TRB was determined as the time after TLS when the smoothed depth during the ensuing 20-second period (a 10-record interval) first changed by 0.1 fsw/min or less. The average

descent rate in the dive was then calculated from raw depth data during only those sections in the TLS→TRB interval in which the local moving average depth change exceeded 3 fsw/min. TLB was determined as the time after TRB when the mean smoothed depth during the next 30 seconds (a 15-record interval) was at least one fsw less than the prevailing smoothed depth. Finally, TFS was determined as the time after TLB when the mean smoothed depth during the next 30 seconds first changed by 0.1 fsw or less.

Summary information for each profile includes the PO_2 minimum and maximum reached during each of three periods in the profile: (1) "RB thru Procedure," defined the period between TRB and when the diver started breathing on the MK 25, (2) "Preascent Delay," defined as the period between when the diver started breathing on the MK 25 and TLB, and (3) "Ascent," defined as the period between TLB and TFS. These three periods in a typical dive are illustrated in Figure 1. Time-weighted average PO_2 during the first two of these periods is also included.

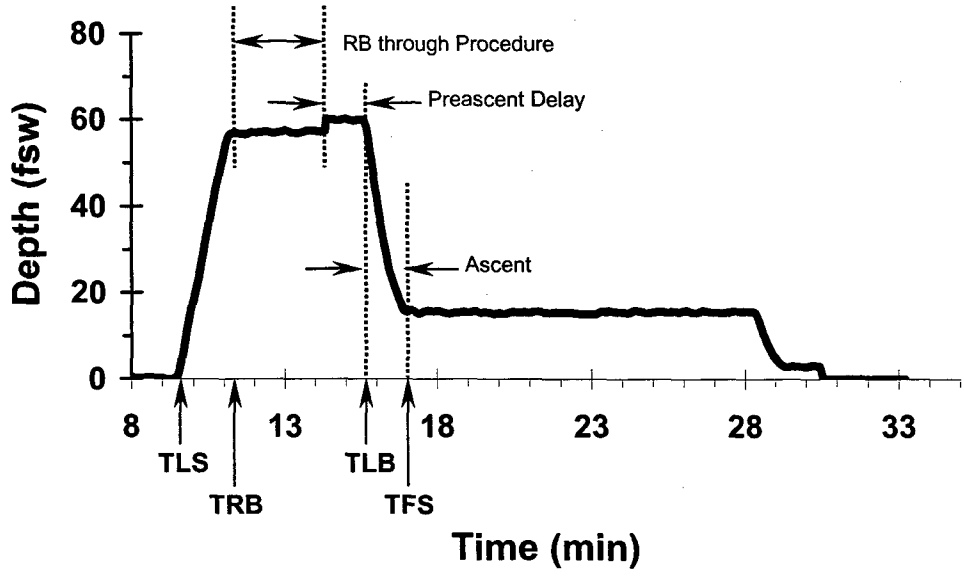

Figure 1. Typical depth versus time profile illustrating the three periods for which PO_2 summary information was compiled.

OSF DIVING PROCEDURE

Divers set up the MK 25 according to standard operating procedures, *but did not perform an O_2 purge.*[7]

Connections for dive instrumentation were completed in the OSF trunk. The divers entered the wetpot and moved to their positions facing each other in buddy pairs on the highstand, where they remained standing with heads and entire torsos, including UBAs, out of the water to simulate LO positions in the ASDS. To allow their MK 25s to equalize during the ensuing compression, the divers placed their mouthpiece barrel valves in

dive position and executed the following de-purge procedure with their O_2 cylinder valves closed:

(a) Deplete MK 25 breathing bag volume by inhaling through mouth from the UBA T-bit and exhaling into the surrounding atmosphere through nose, repeating until bag is empty;

(b) Add air to the MK 25 bag by inhaling chamber air through the nose and exhaling into MK 25 via the T-bit, repeating until bag is at a comfortable breathing volume.

(c) Repeat steps (a) and (b) four times;

(d) Medical Deck personnel check UBA PO_2. Proceed with chamber press to LO depth if UBA PO_2 between 0.16 ATA and 0.22 ATA, as registered via the R10-DS O_2 fuel cell. If UBA PO_2 exceeds 0.22 ATA, repeat steps (a), (b) and (d).

Upon reaching 57 fsw, as indicated on the Charlie Manual Operation Panel (MOP) digigauge, divers executed instructions transmitted from the Medical Deck via the trunk tender on how to prep their rigs before submerging three feet below the water's surface. To try to rectify procedural deficiencies that arose as the study continued, investigators modified these instructions twice during the protocol.

Subjects on dives 1–58 received the original instructions: "At the end of a normal inhalation, go on your rig, exhale one tidal volume breath of chamber air into your MK 25, open your O_2 bottle (all the way open and back one-quarter turn), immediately submerge your head, and move from the highstand to the middle platform in the OSF."

The low PO_2 safety criterion ($PO_2 \leq 0.16$ ATA) was violated during the delay at depth in four dives performed with this procedure, a result raising the suspicion that chamber air was being pressed back into the breathing bags during compression, was increasing bag volume, and was delaying subsequent actuation of the O_2 add-valve. This train of events would have increased the likelihood of hypoxia before ascent.

Accordingly, subjects in dives 59–77 performed a modified procedure intended to decrease their MK 25 breathing bag volumes before they submerged. They received the following pre-submergence instruction: "Completely empty your breathing bag, inhaling through your mouth and exhaling through your nose. When the bag is flat, take one normal inspiration through your nose and exhale it into the rig; open your O_2 cylinder valve, immediately submerge your head, and move from the highstand to the middle platform in the OSF."

Despite this procedural modification, an additional hypoxic event occurred. To increase the initial UBA PO_2 in dives 78–92, therefore, it was decided to add a one-second manual O_2 addition to the procedure before divers submerged. Divers were thus given the following presubmergence instruction: "Completely empty your breathing bag, inhaling through your mouth and exhaling through your nose. When the bag is flat, take one normal inspiration through your nose and exhale it into the rig, open your O_2 cylinder valve, perform a one-second manual O_2 addition, and immediately submerge your head and move from the highstand to the middle platform in the OSF."

in all cases, the OSF was decompressed to 15 fsw at a rate of 30–60 ft/min after the scheduled delay at depth was completed. Divers breathed in an open-circuit manner during ascent by making short inhalations from the MK 25 followed by slow, prolonged exhalations through the nose. Divers were instructed to avoid exhaling into the MK 25. If they found that this breathing pattern was insufficient to prevent overinflation of the UBA ("chipmunk cheeks"), they were advised to allow some air to "burp past" their T-bit mouthpieces. The Dive Watch Supervisor reported depths every 10 fsw on ascent to 15 fsw so that divers could anticipate the amount of exhaled air volume required to ascend safely.

After reaching 15 fsw, divers executed a two-empty/fill underwater UBA purge procedure. Each diver first completely emptied his breathing bag by inhaling from his UBA and exhaling through his nose, and then completely filled his bag with oxygen by activating his O_2 add valve for 6 seconds or until he sensed his bag pressing on his chest. This sequence was then repeated, ending with a UBA bag volume comfortable for swimming. The OSF remained at 15 fsw for 10 minutes before traveling to the surface at a rate of 30 ft/min. On the surface, divers stopped breathing from their rigs, secured their mouthpieces in "surface mode," and closed their oxygen bottle cylinder valves. Divers then exited the OSF in the reverse order of their entry.

Divers that developed problems at any time during the evolution were instructed to take the appropriate action (e.g., to manually add O_2 to their rigs if UBA PO_2 fell below 0.16 ATA), move to the highstand, go off their rigs, and breathe chamber air for the remainder of the dive.

Post-dive debriefs were conducted after each dive to solicit diver feedback and confirm that the procedures had been performed as intended. All deviations from the intended LO procedure were noted in the investigator's log.

RESULTS

DATA SUMMARY

Of 92 dives undertaken, one was aborted because of O_2 fuel cell malfunction, and another was aborted because of water in the rig. Two additional dives were aborted when the divers failed to open their O_2 cylinder valves as they had been instructed. The remaining 88 dives, completed by 37 different divers, provided data suitable for analysis. Eighty-one dives (81/88) were successfully completed without violating PO_2 safety criteria. One example of such a dive is presented in Figure 2. Seven dives (7/88) resulted in violations of PO_2 safety criteria and were aborted. Examples of such dives are given in Figures 3 and 4. Complete depth and inspired PO_2 profiles for all 88 dives are illustrated in Appendix A, and summary PO_2 data are tabulated in Appendix B.

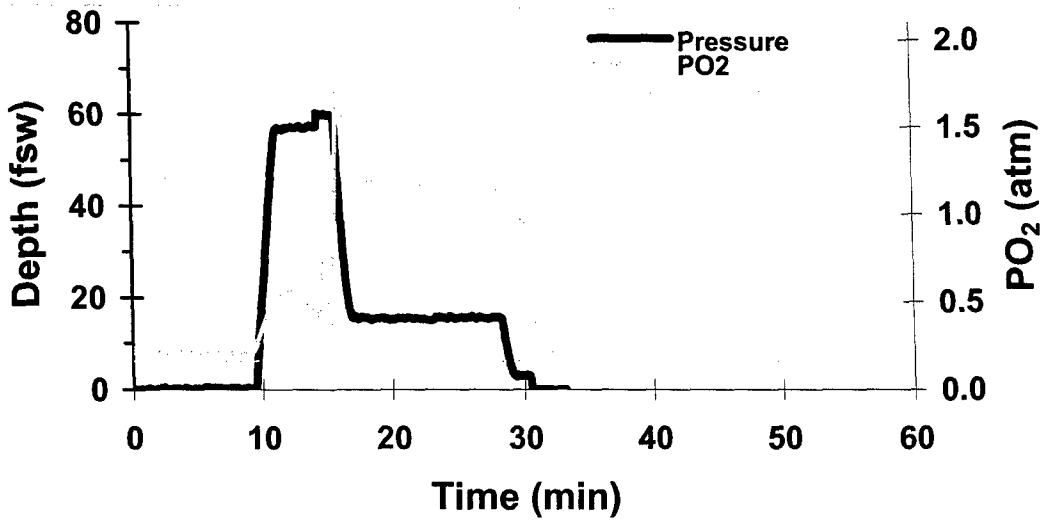

Figure 2. A depth and PO_2 versus time profile for a dive completed without violating PO_2 safety criteria. Dashed lines indicate minimum (0.16 ATM) and maximum (1.7 ATM) PO_2 markers (Appendix A: Dive 1).

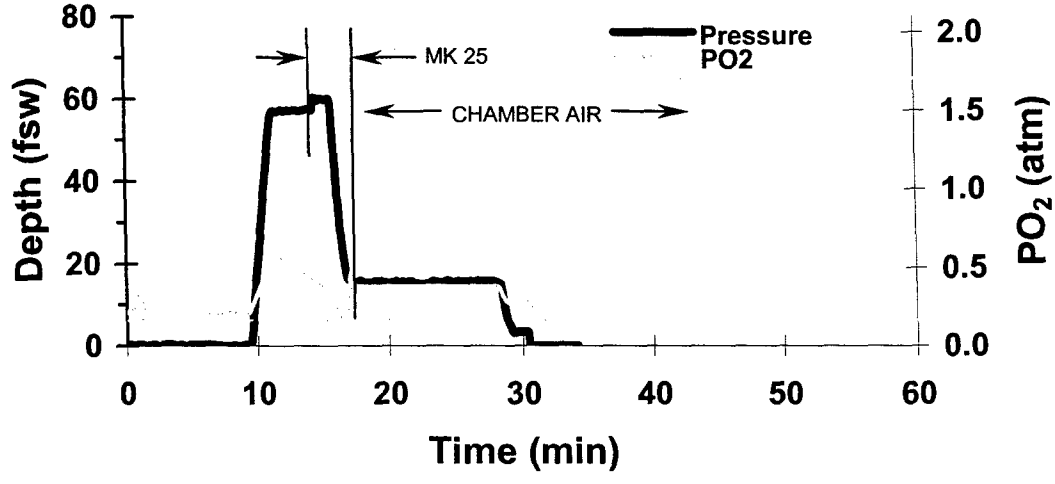

Figure 3. A depth and PO_2 versus time profile for a dive in which the low PO_2 safety criterion was violated during ascent. Dashed lines indicate minimum (0.16 ATM) and maximum (1.7 ATM) PO_2 markers. The diver started breathing chamber air at approximately 18 minutes (Appendix A: Dive 7).

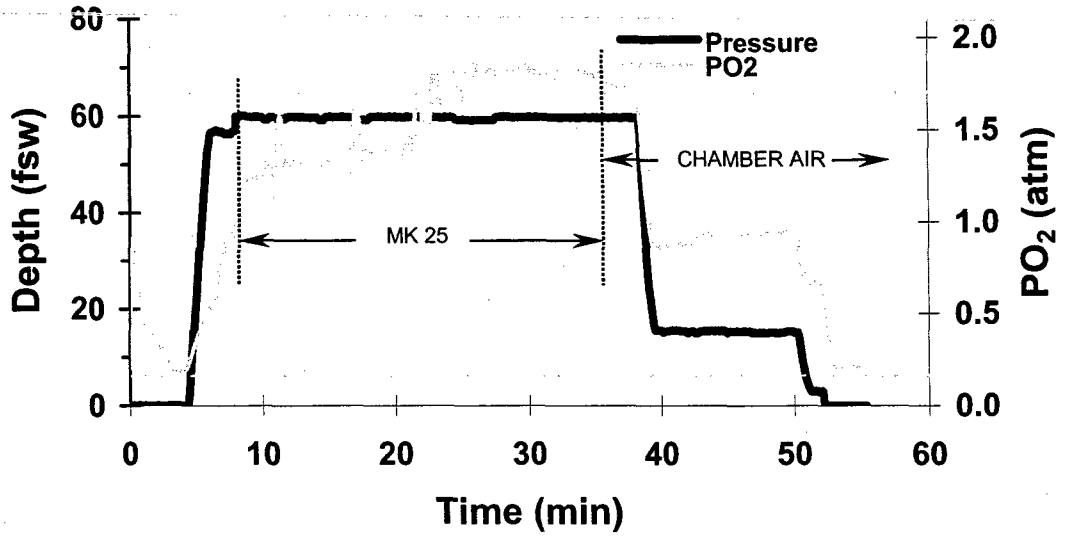

Figure 4. A depth and PO_2 versus time profile for a dive in which the high PO_2 safety criterion (PO_2 > 1.7 ATM for longer than 10 minutes) was violated in the preascent delay period. Dashed lines indicate minimum (0.16 ATM) and maximum (1.7 ATM) PO_2 markers. The diver started breathing chamber air at 37 minutes (Appendix A: Dive 84).

PO_2 OUTCOMES

Incidents of observed PO_2 outcomes under each delay condition are given in Table 1. No dives resulted in $PO_2 \geq 2.4$ ATA. Five dives resulted in $PO_2 \leq 0.16$ ATA, and two dives resulted in $PO_2 \geq 1.7$ ATA for 10 minutes. Violations of PO_2 safety criteria (n = 2) in the one-minute delay condition occurred during ascent to 15 fsw. Violations of PO_2 safety criteria occurred during 10-minute (n = 3) and 30-minute (n = 2) delays at depth. Air leaked from the mask and violated PO_2 safety criteria (n = 2) during the 30-minute delay. Symptoms associated with these violations occurred only once (Dive 49), in a diver pulled for $PO_2 \leq 0.16$ ATA during the 10-minute delay. However, he reported the symptoms, which he described as "warm and tingly" lips and legs, only during the postdive interview, when he also noted that all symptoms completely resolved within seconds after he began breathing chamber air.

Table 1.
Frequency of PO_2 Outcomes*

Delay at Depth (min)	Acceptable PO_2	$PO_2 \leq 0.16$	$PO_2 \geq 1.7$
1	23	2	0
10	32	3	0
30	26	0	2

*The first four dives with $PO_2 \leq 0.16$ occurred under the original procedure, in which the UBA was emptied only before descent. One incident of low PO_2 occurred after the procedural modification that included a second UBA emptying at depth (during a 10-minute delay). Both dives with $PO_2 \geq 1.7$ occurred under the final procedure tested, that which included a manual O_2 addition after the second UBA emptying at depth (see p. 4 for details).

Table 2 lists the binary confidence limits for observed incidents of PO_2 safety criteria violations at each delay.

Table 2.
Binary Confidence Limits for the probability of Violating PO_2 Criteria*

Delay at Depth (min)	Confidence Limits (99%)
1	0.004 – 0.320
10	0.009 – 0.279
30	0.003 – 0.290

*$PO_2 \leq 0.16$ ATA or $PO_2 \geq 1.7$ ATA for 10 min.

DISCUSSION

The ASDS is a small, dry submarine capable of supporting a wide range of operational scenarios and depths. It allows Navy SEALS to leave the host submarine and approach targets in an environment that reduces the impact of environmental stressors on physical readiness. Since the ASDS is larger than the current delivery vehicle, it may be desirable to perform LO operations at depths greater than 20 fsw to avoid detection from the surface.

Original ASDS LO plans involved using an air hookah system that would allow SEALS to lock out from a minimum depth of 60 fsw. This system included an ascent line up to a transit depth of 15 to 20 fsw, where divers could shift from air to the MK 25 UBA. For several engineering reasons, the hookah system did not become available, and no plans for installing it exist. Therefore, this research simulated procedures for LO with the MK 25.

The problem with using the MK 25 during a LO procedure at 60 fsw is the possibility of encountering unacceptably low or high diver-inspired PO_2. Markers of hypoxia and hyperoxia were selected as safety parameters for our simulated LO procedures. One diver reported symptoms associated with $PO_2 \leq 0.16$, a report suggesting that the low PO_2 safety criterion was not excessively conservative. High PO_2 safety criteria were related to losing an operational excursion or provoking CNS O_2 toxicity. Symptoms associated with CNS O_2 toxicity were not reported in the two incidents of high PO_2 that occurred in the present dives.

Lockout procedures tested in this study were designed to trap nitrogen (N_2) in the MK 25 closed-circuit breathing loop in order to dive the UBA as a de facto nitrox rig at depth. This design intent was accomplished by having divers employ the de-purge procedure (p. 4) on air in the simulated ASDS moon pool before exiting the ASDS at LO depth. After this procedure at 60 fsw, the PO_2 in the MK 25 and in the diver's lungs is approximately 0.59 ATA, a level that poses no risk of hypoxia or CNS O_2 toxicity. However, the MK 25 O_2 add-valve does not actuate until the breathing bag decreases to a threshold minimum volume. A sufficiently large initial MK 25 volume of air may

consequently support diver respiration for several minutes before the breathing bag volume decreases to the point where the O_2 add-valve actuates. Under such conditions, inspired PO_2 will continue to fall. The diver may either become seriously hypoxemic at depth or during subsequent ascent, when further pressure-driven PO_2 decreases occur. For example, if a diver leaves 60 fsw with a PO_2 less than 0.40 ATA and his O_2 add-valve has not actuated, he may become hypoxic before he reaches transit depth (15 to 20 fsw). All of the PO_2 safety violations (n=2) after one-minute delay at depth were hypoxic events during ascent in accord with this scenario. If a diver's delay time is less than 10 minutes, he should therefore be instructed to perform a two-second manual O_2 addition before ascent, to avoid hypoxia as his PO_2 decreases during that ascent.

If the breathing bag is not overinflated at the start of the LO procedure, the O_2 add-valve will actuate, add oxygen as it is consumed, and increase the UBA PO_2. As long as the initial N_2 content is retained in the closed loop, PO_2 will approach a steady state, where it will be maintained indefinitely. However, any lost N_2 will be replaced by O_2, causing UBA PO_2 to increase to potentially unacceptable levels depending on depth. Two such cases occurred during the longest delay time tested (30 min), with inspired PO_2 increasing to values greater than 1.7 ATA for more than 10 min. These exposures had PO_2 values in excess of that incurred by breathing 100% O_2 at 20 fsw, and because these PO_2 values persisted for more than 10 minutes, the exposures exceeded the threshold to be counted as an excursion in MK 25 diving. Operational occurrence of such an exposure would consequently force the LO to be logged as the only O_2 excursion allowed under current O_2 exposure limits in the *U.S. Navy Diving Manual*.[8] Such use of the only allowed excursion during LO must be avoided, because divers will also need to lock in to the ASDS at the end of the mission. This lock-in (LI) will presumably occur at a depth greater than 20 fsw, and consequently require its own excursion. Interviewed operators indicated that such an LI might also have a delay as long as 30 minutes. To address this possibility, future testing should include the 60 fsw LO, a mission swim with one excursion, a return swim, and a 30-minute delay before LI.

Although we observed seven PO_2 safety criteria violations in 88 LO procedures, the safety of using the MK 25 in operational LO procedures at depth remains uncertain. While immersed in euthermic water, our test subjects wore shorts and t-shirts and were completely at rest. They were therefore breathing the MK 25 in a slow, shallow fashion with presumably very little consumed O_2. Operational conditions (i.e., cold water and exercise) should induce greater O_2 consumption, trigger earlier and more reliable O_2 add-valve actuation, and reduce the likelihood of low PO_2 events. Similarly, divers in the present tests remained in an upright (vertical) position. Postdive interviews suggested that having divers in a horizontal swim position might reduce their work of breathing and air leakage, and thereby foster their retention of residual N_2 in the UBA and mitigate the likelihood of unacceptably high PO_2 events. In any case, one essential observation is clear: adherence to procedure is critical to overall success. A dive supervisor in the ASDS moon pool will almost certainly be required to ensure that divers comply with all aspects of the procedure. Such function would be facilitated by use of a pre-dive check-off sheet, and include performance of a hands-on check on each diver to ensure breathing bags are not over-inflated, O_2 cylinders are open, etc.

Additional considerations for future testing should include operational water temperatures and having divers perform light exercise in a prone, horizontal (swim) position at depth on cycle ergometers.

CONCLUSIONS AND RECOMMENDATIONS

- Seven incidents of unacceptably low or high inspired PO_2 occurred during 88 LO procedures at 60 fsw.
- Unacceptably low or high PO_2 might be mitigated by light exercise, operational water temperatures (cold), procedural modifications, and training — all of which require further testing.
- Open water LO procedures using the MK 25 at 60 fsw are not recommended at this time.

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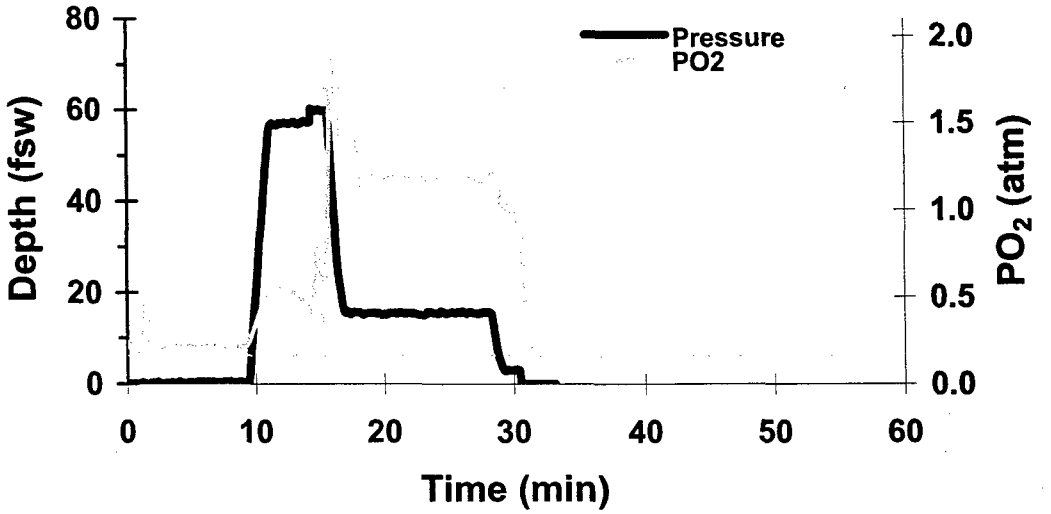
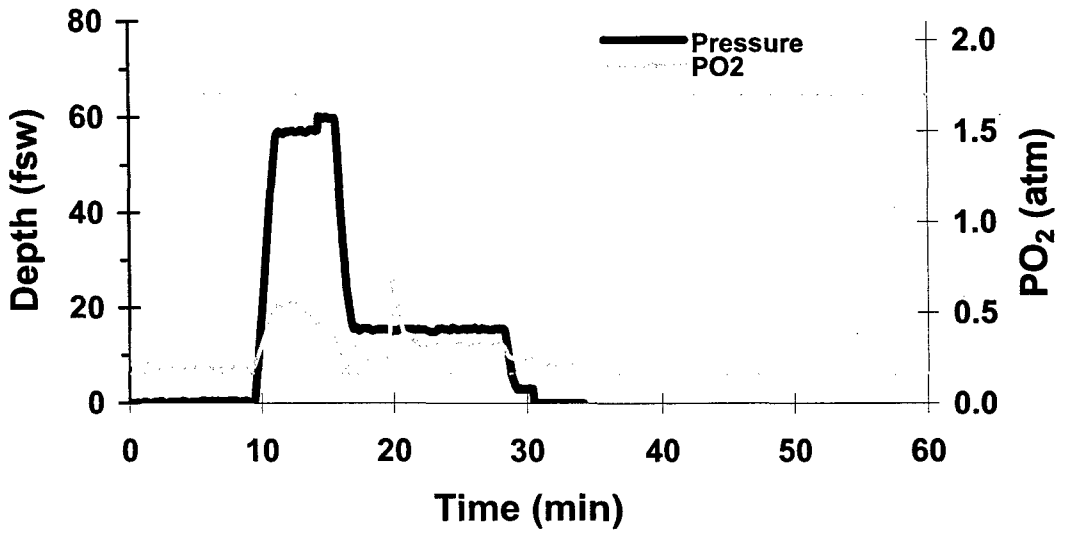
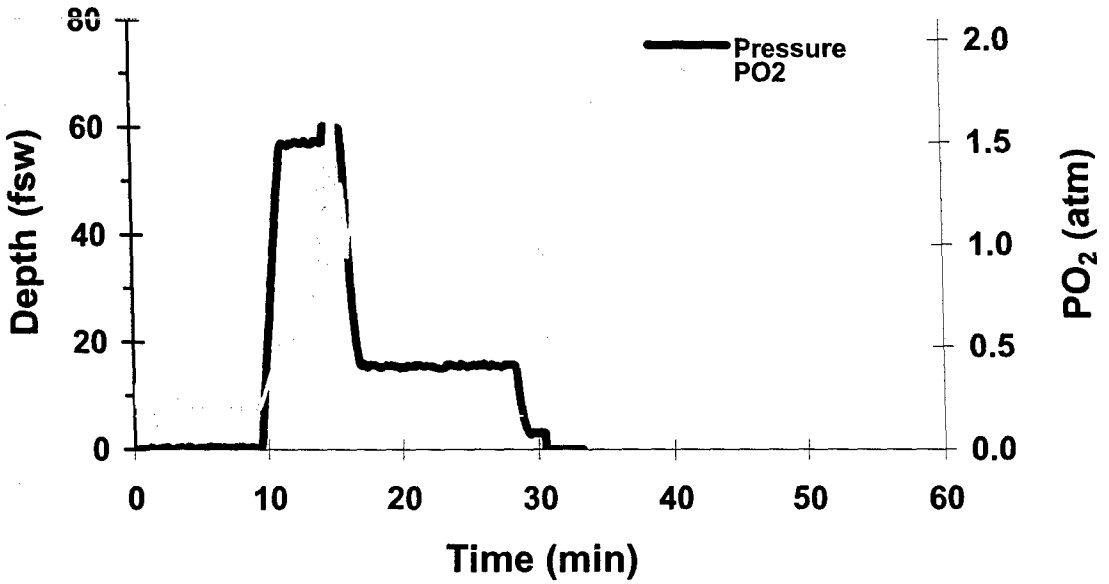
APPENDIX A: Depth and PO_2 vs. Time



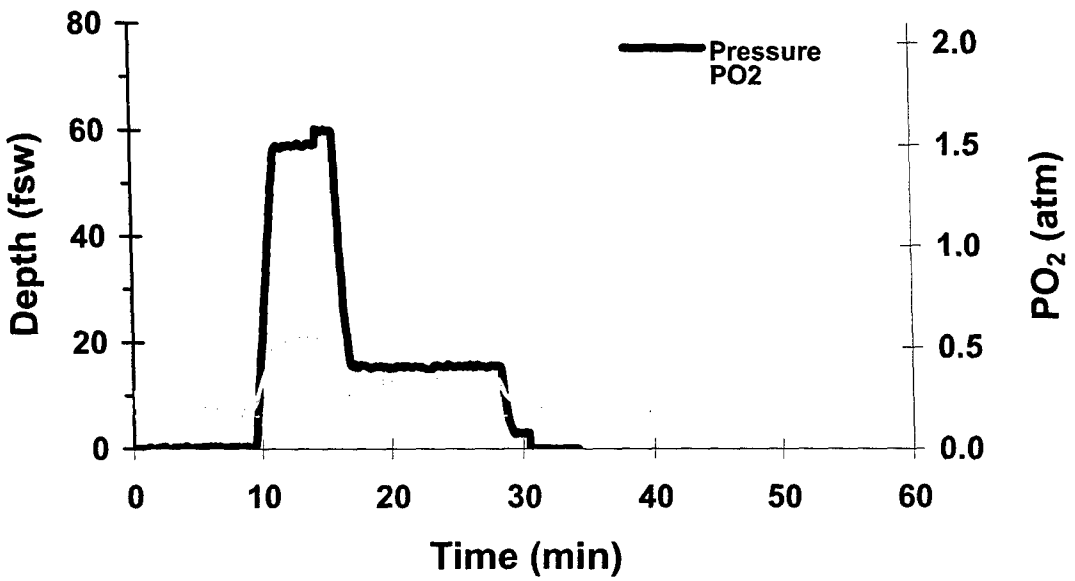
Dive 1. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



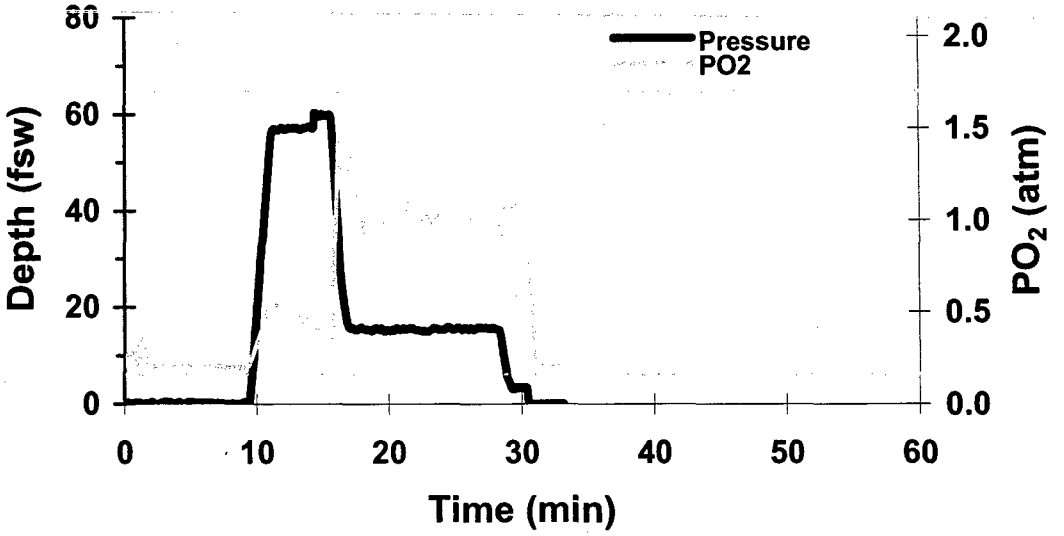
Dive 2. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Diver pulled; $PO_2 \leq PO_{2min}$ during ascent.



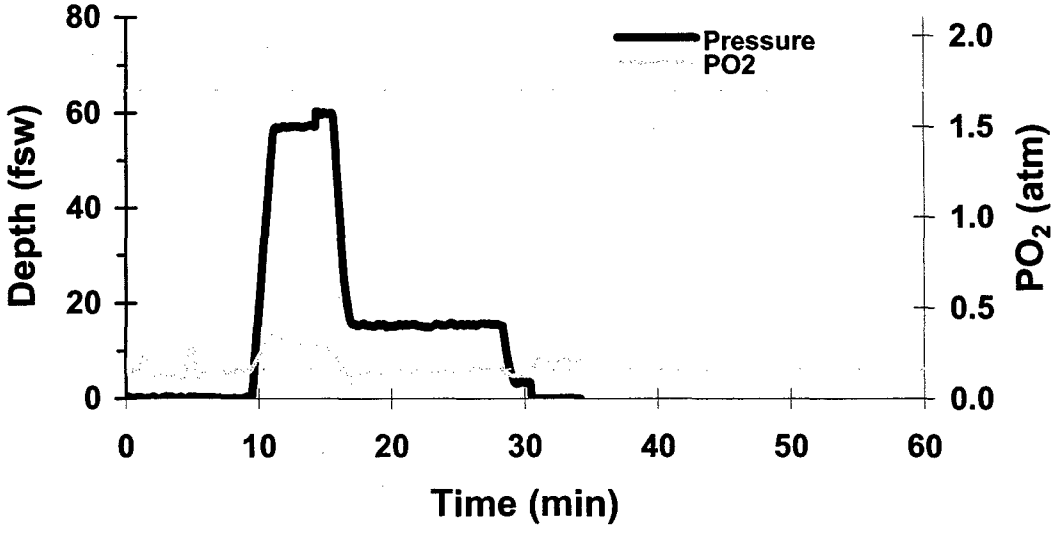
Dive 3. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



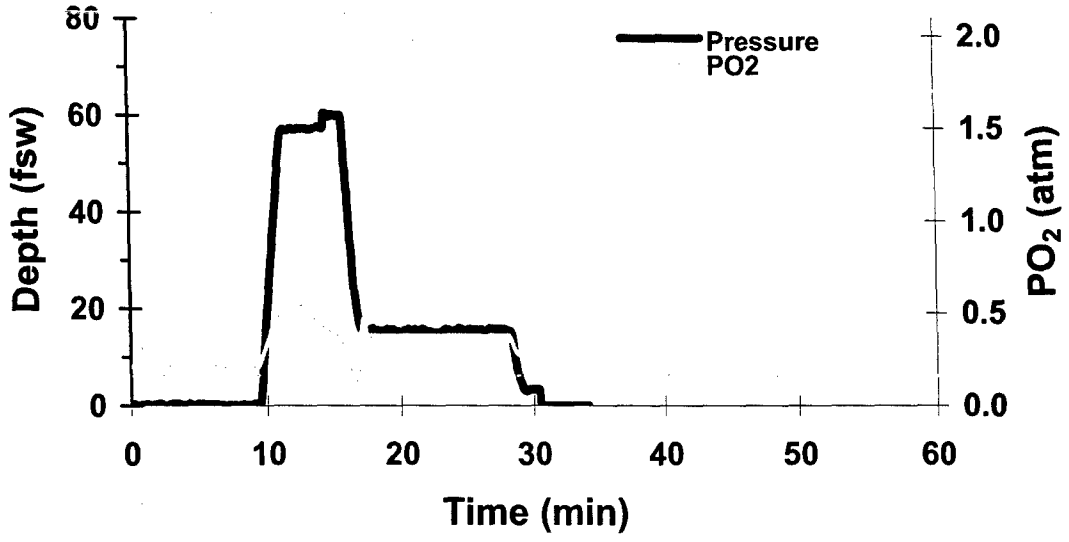
Dive 4. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive aborted before leaving surface due to H_20 in the rig.



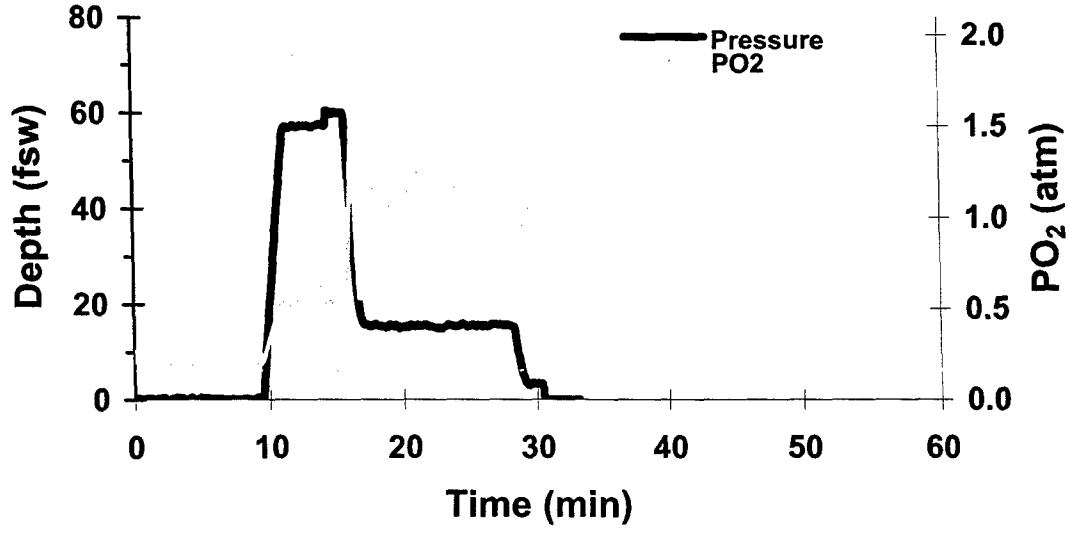
Dive 5. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



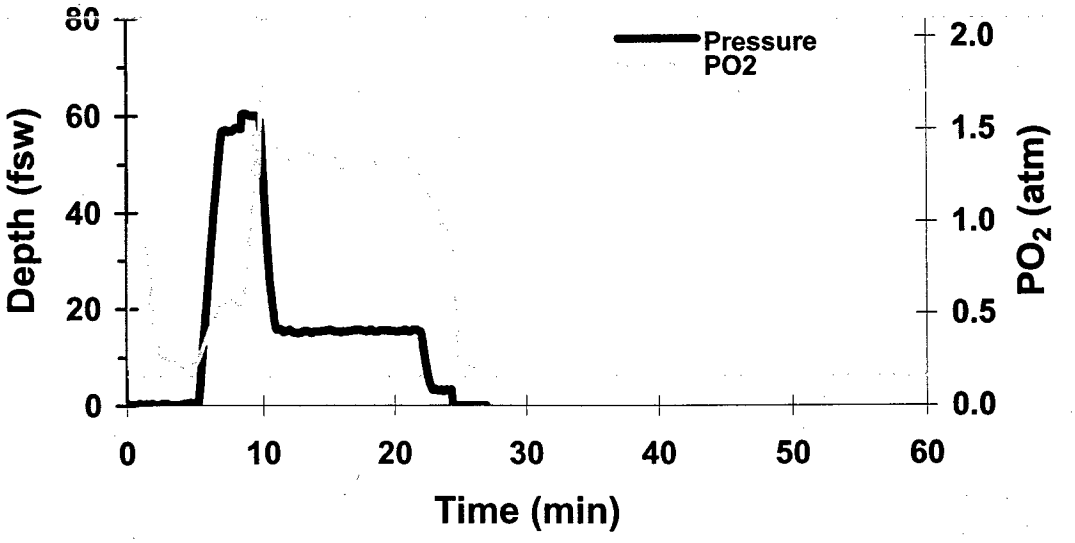
Dive 6. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Aborted before leaving surface due to defective O_2 fuel cell. Diver position lost for remainder of study (maximum number of divers in the OSF reduced from 8 to 7.)



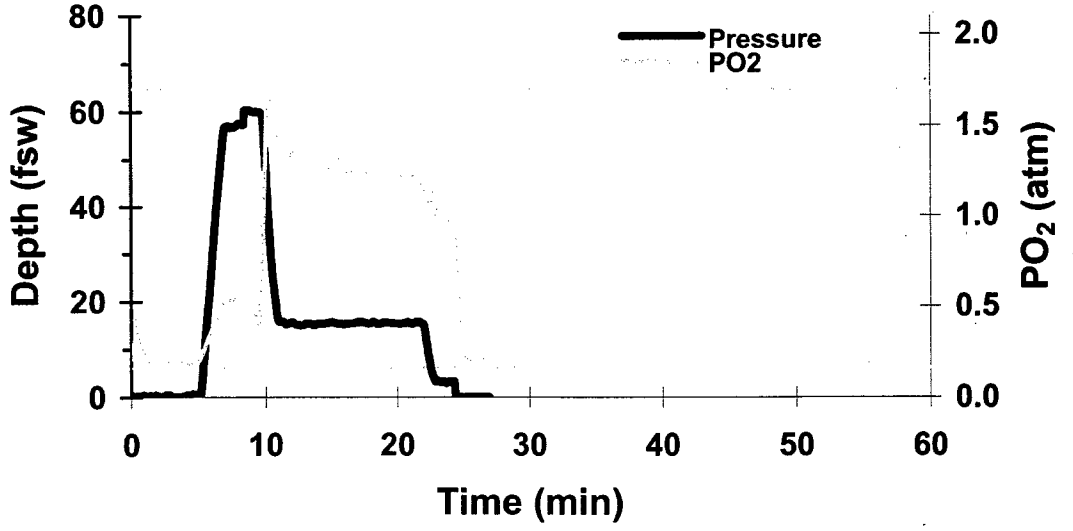
Dive 7. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Diver pulled; $PO_2 \leq PO_{2min}$ during ascent.



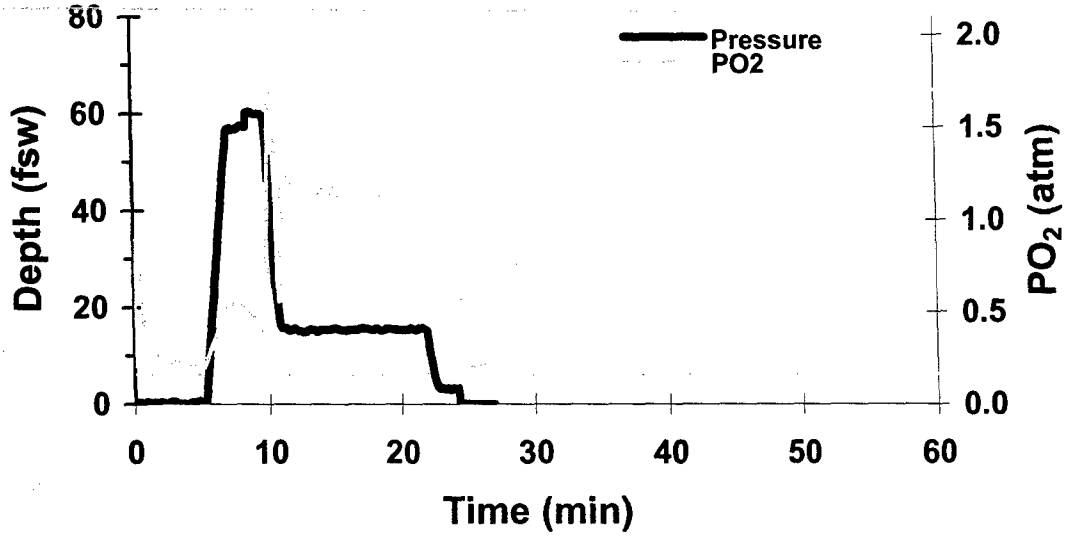
Dive 8. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



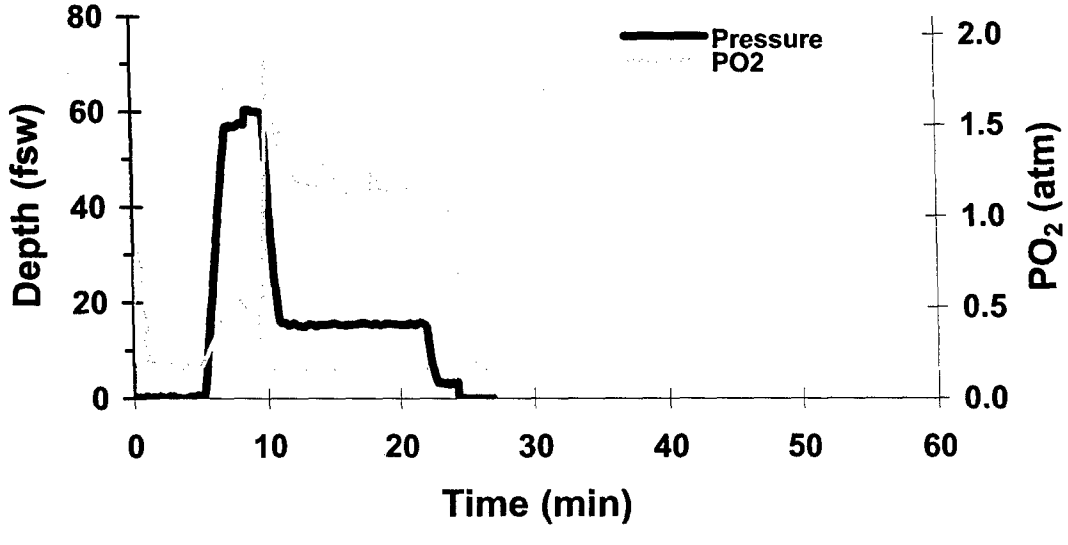
Dive 9. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Unexplained increased noise in signal. Dive completed without violating PO_2 safety criteria.



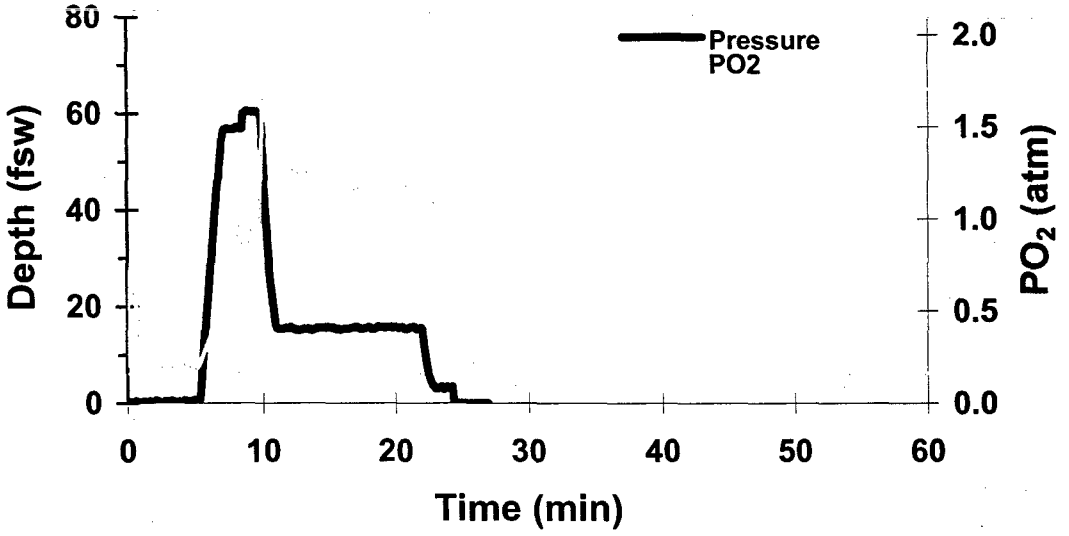
Dive 10. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



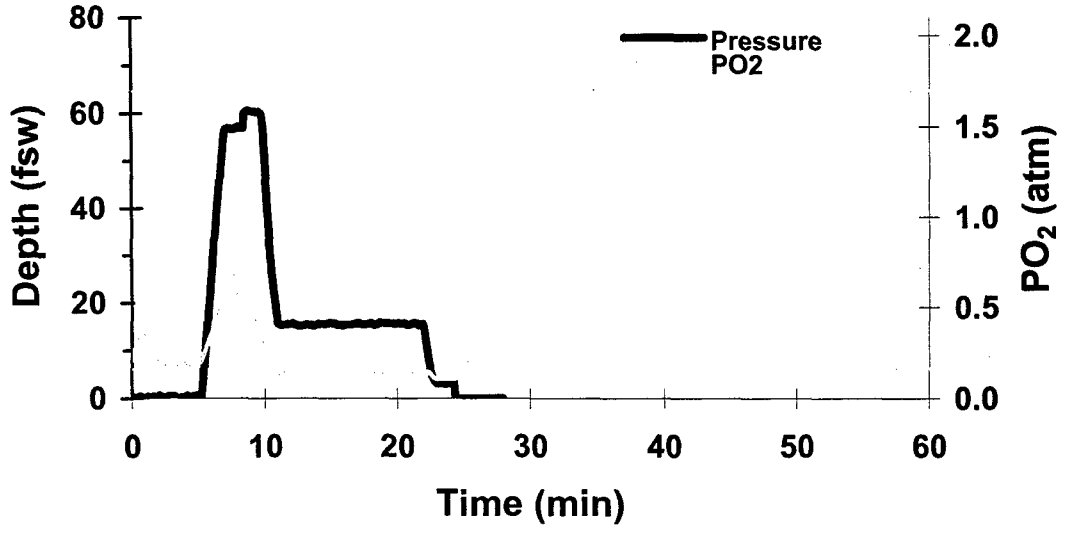
Dive 11. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



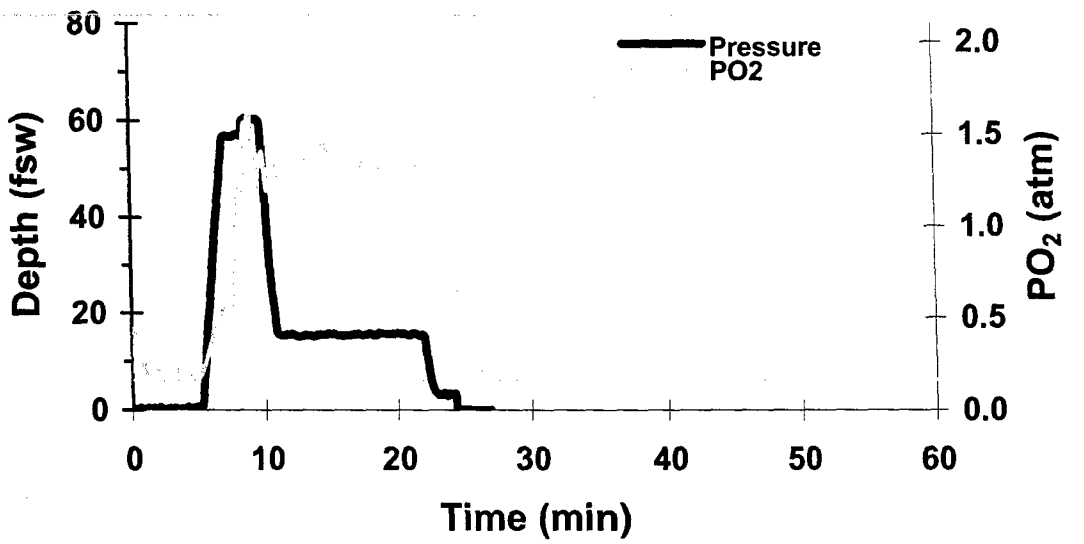
Dive 12. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



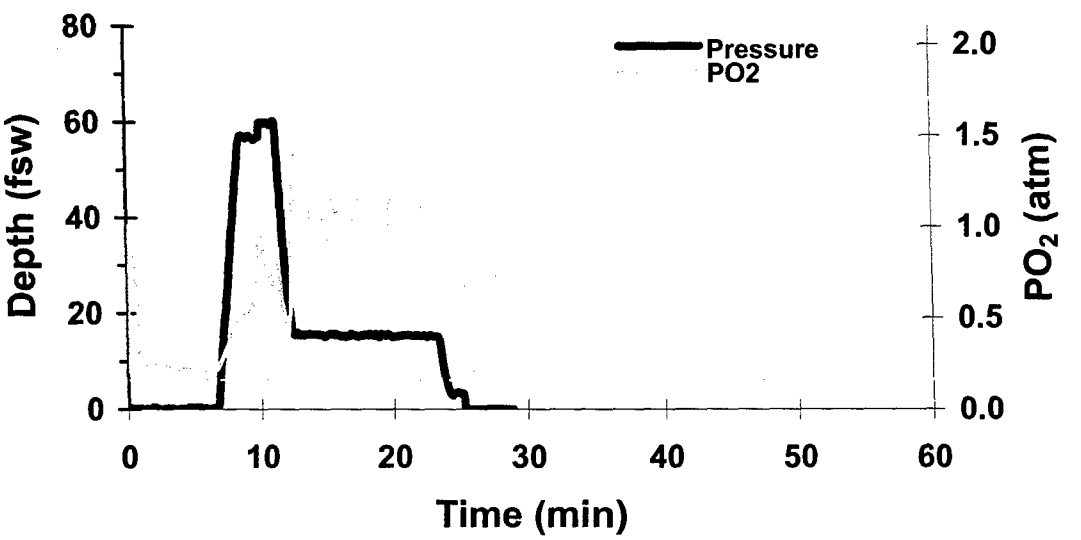
Dive 13. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



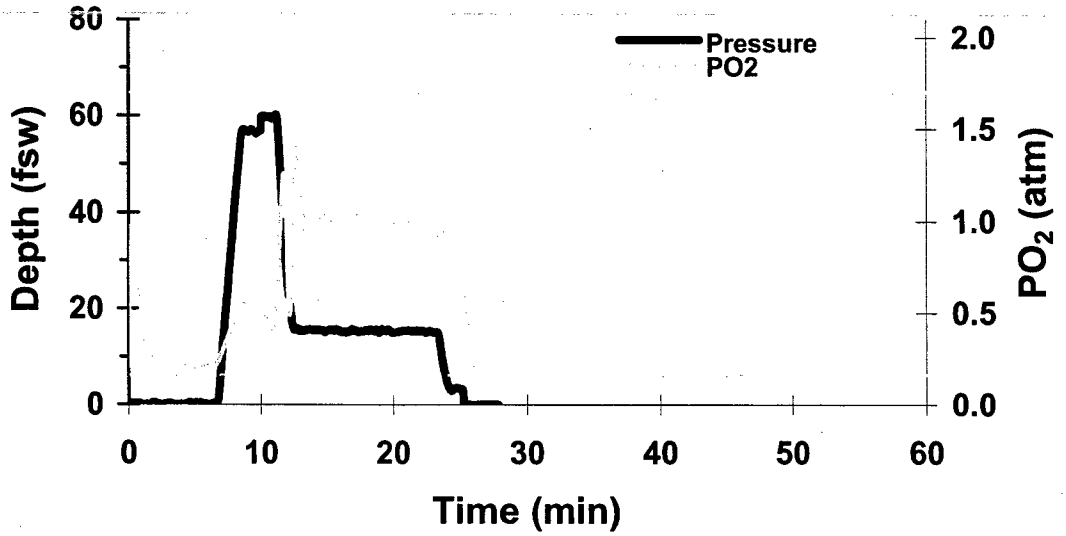
Dive 14. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive aborted due to $PO_2 \leq PO_{2min}$. O_2 bottle was closed, therefore data was not included during analyses.



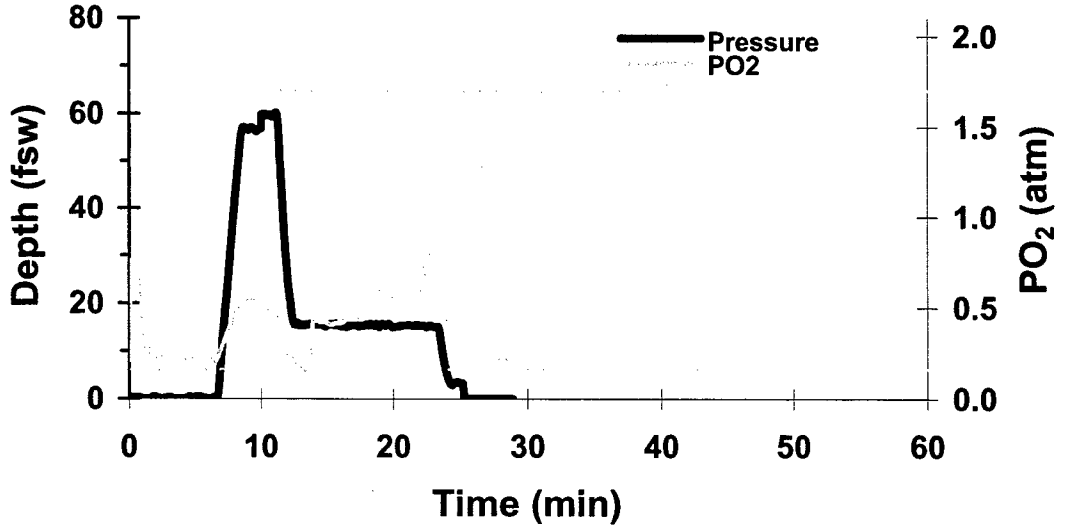
Dive 15. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Unexplained increased noise in signal. Dive completed without violating PO_2 safety criteria.



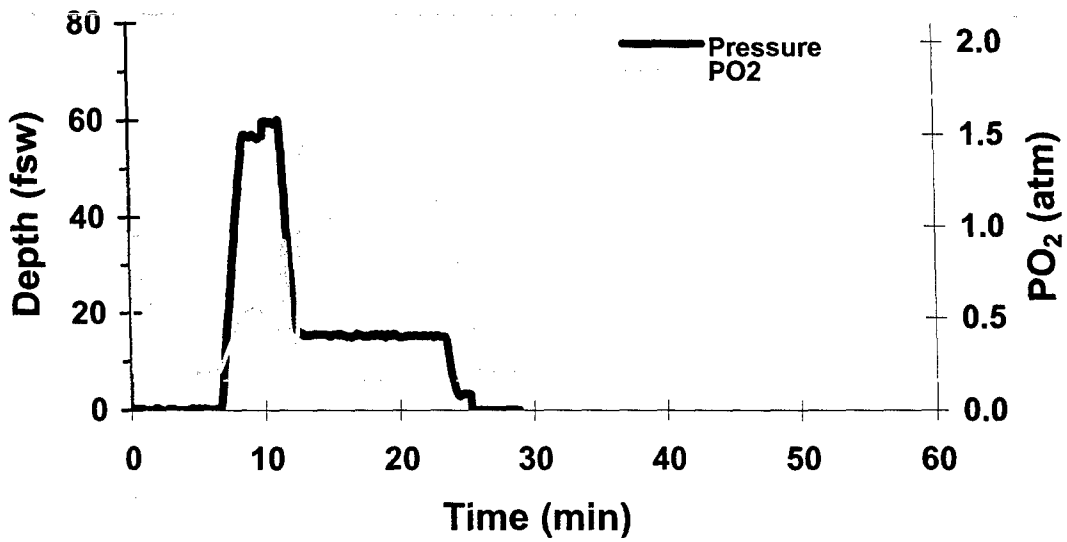
Dive 16. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



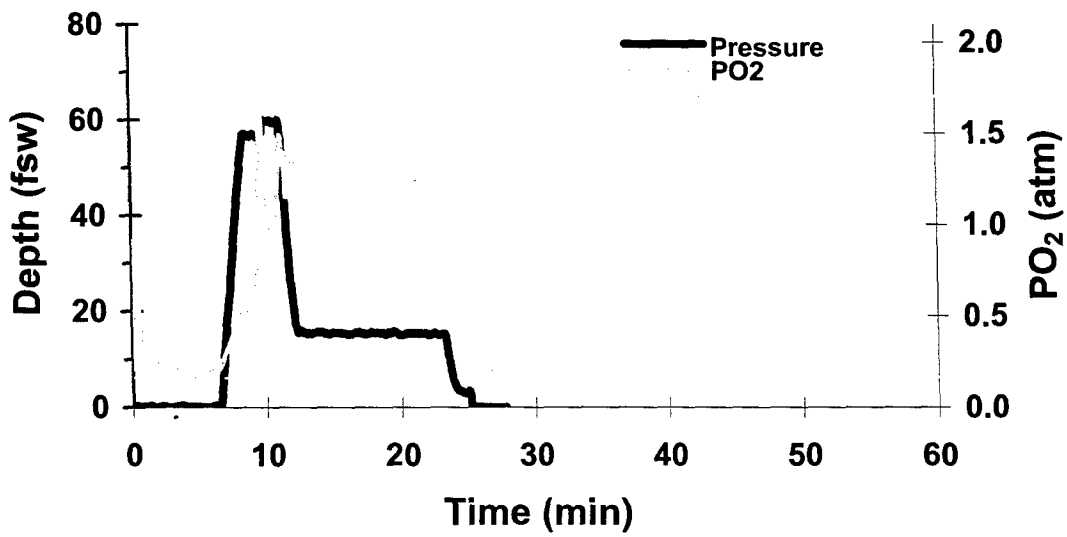
Dive 17. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



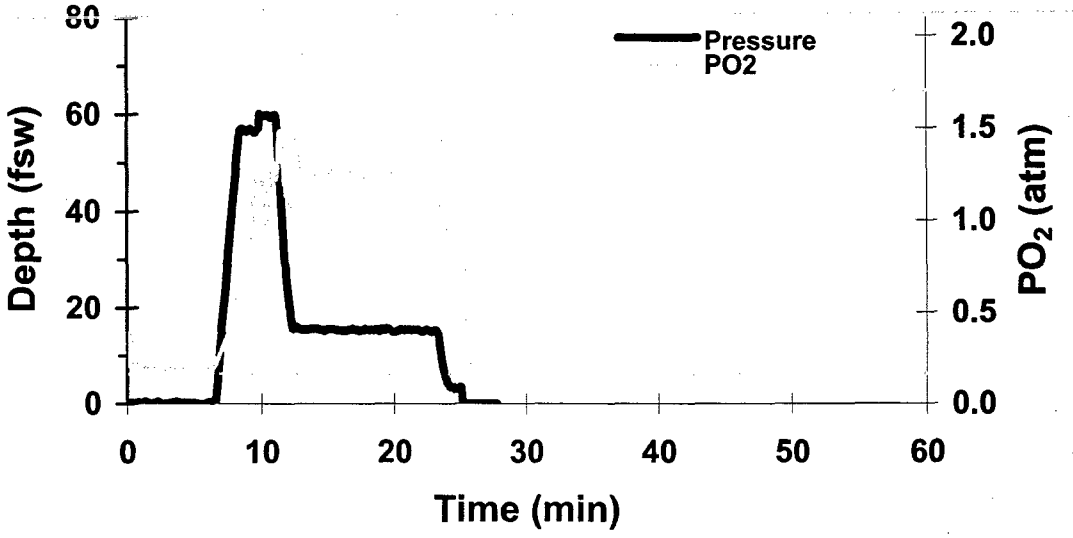
Dive 18. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive aborted due to $PO_2 \leq PO_{2min}$. O_2 bottle was closed; not included in data analyses.



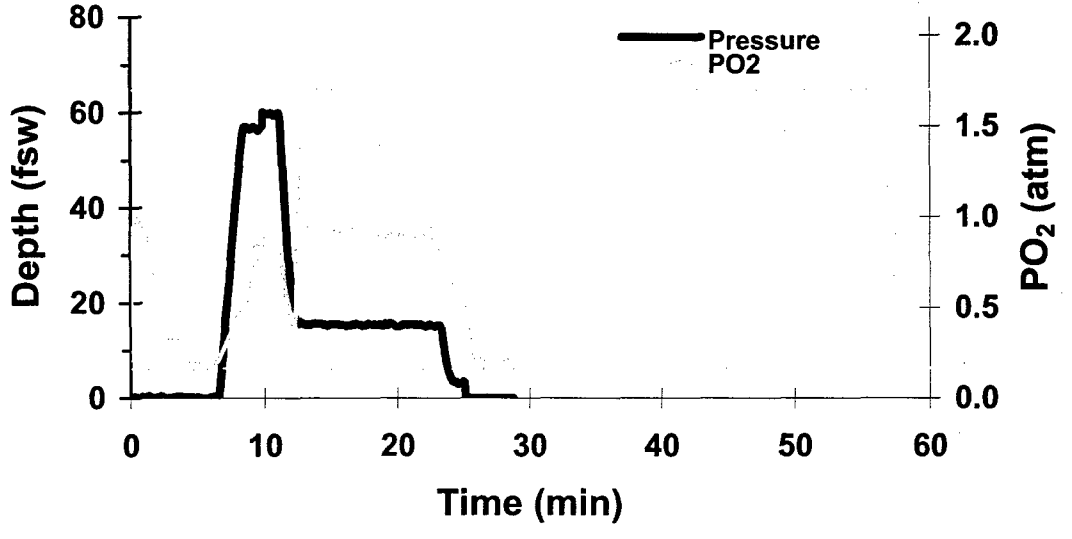
Dive 19. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



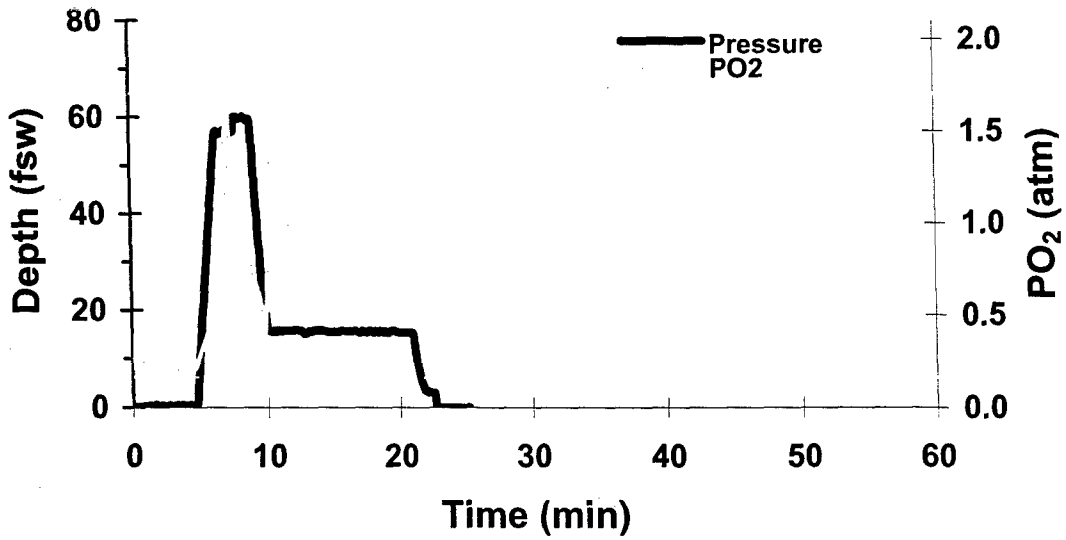
Dive 20. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



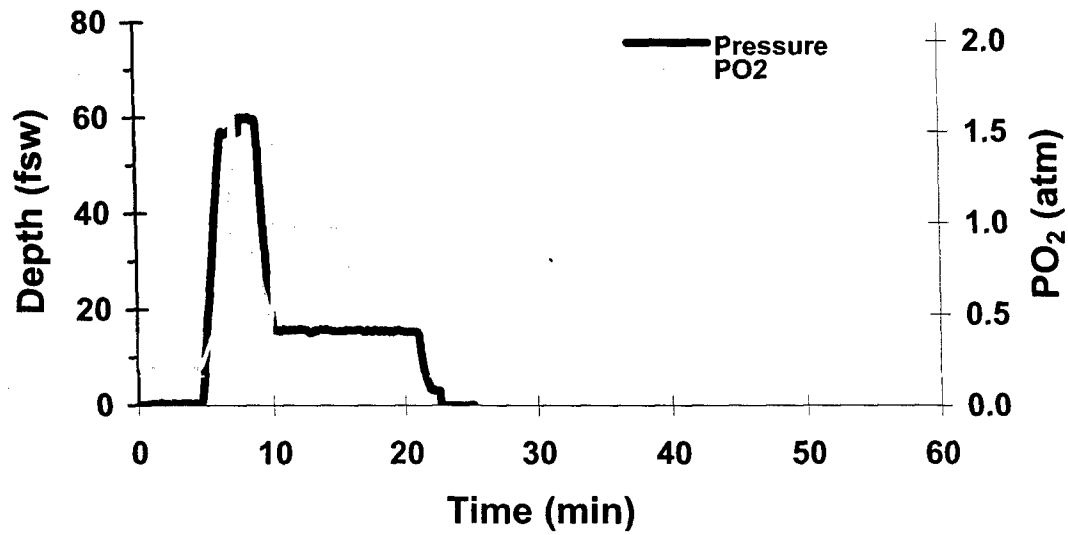
Dive 21. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



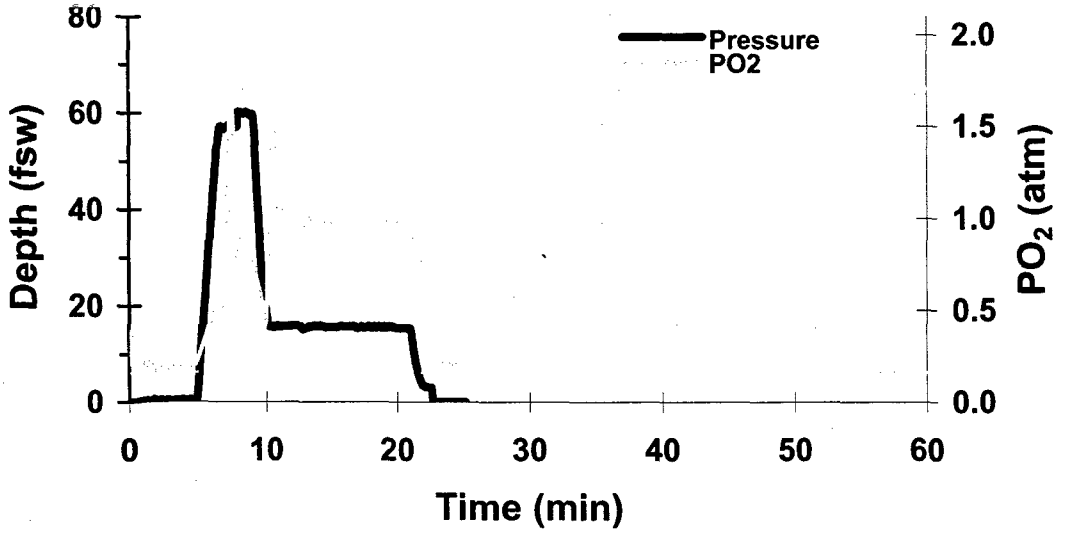
Dive 22. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



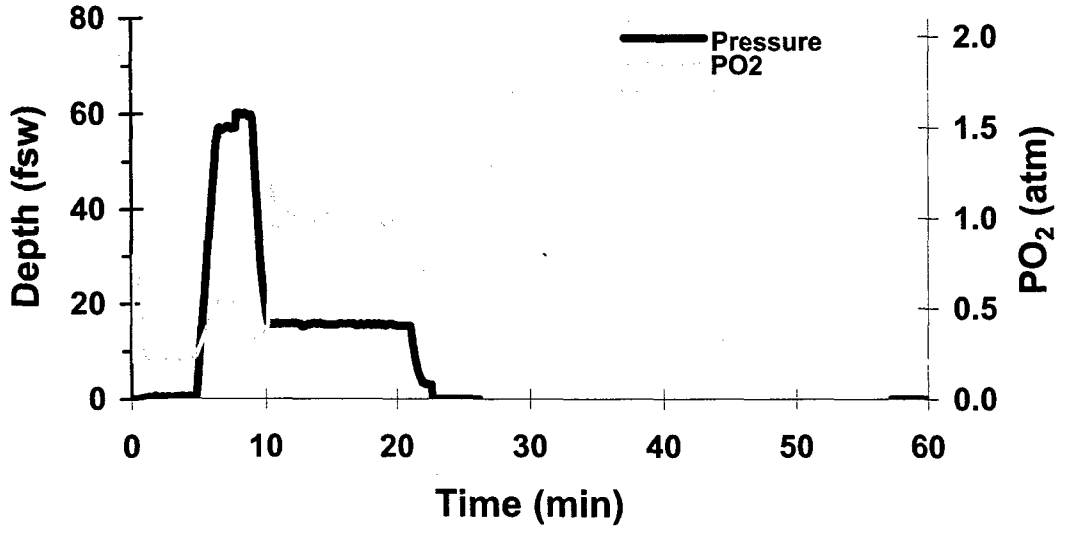
Dive 23. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



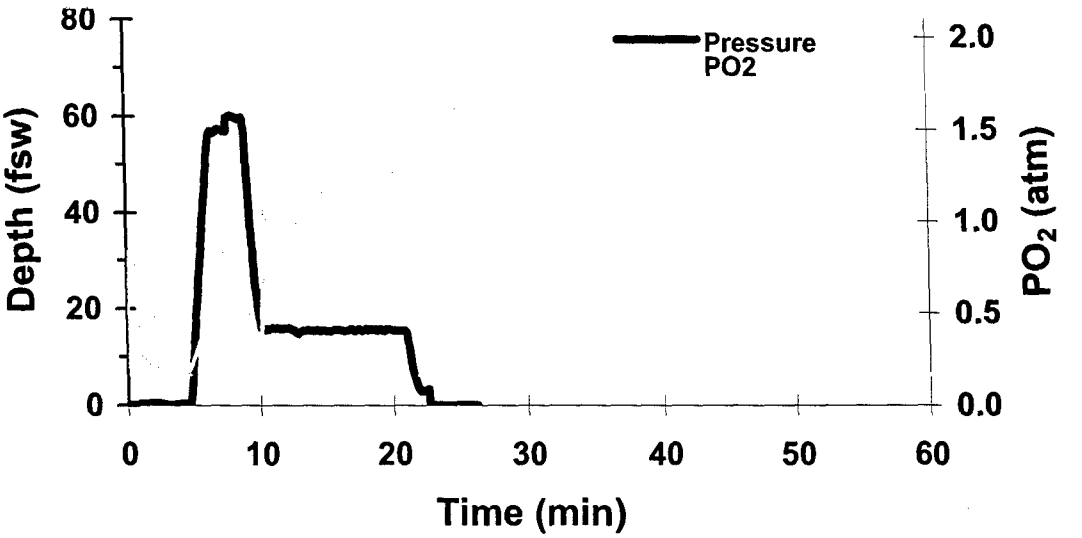
Dive 24. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



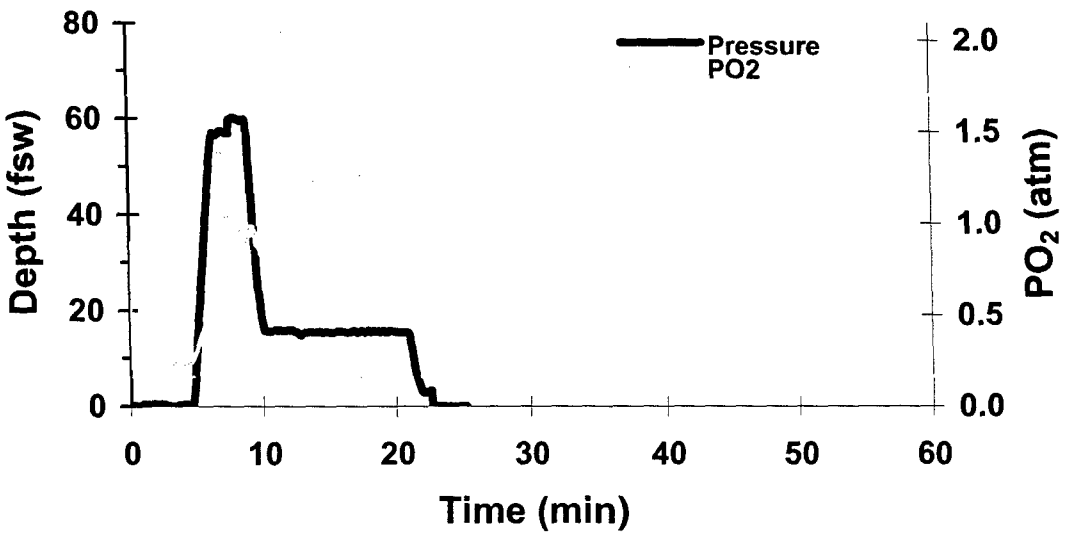
Dive 25. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



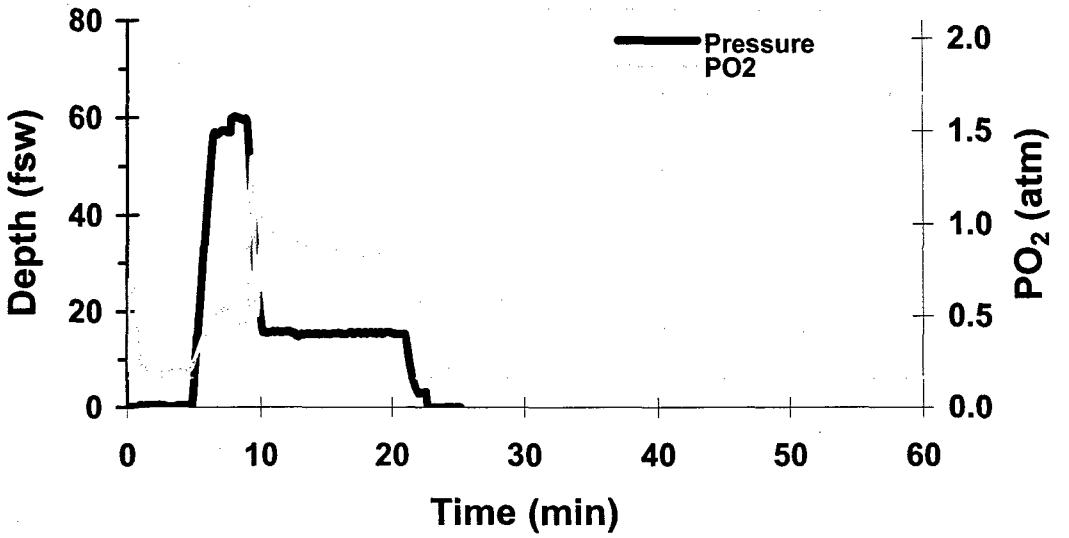
Dive 26. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. $PO_2 < PO_{2min}$ at O2 valve actuation. Dive completed without violating PO_2 safety criteria.



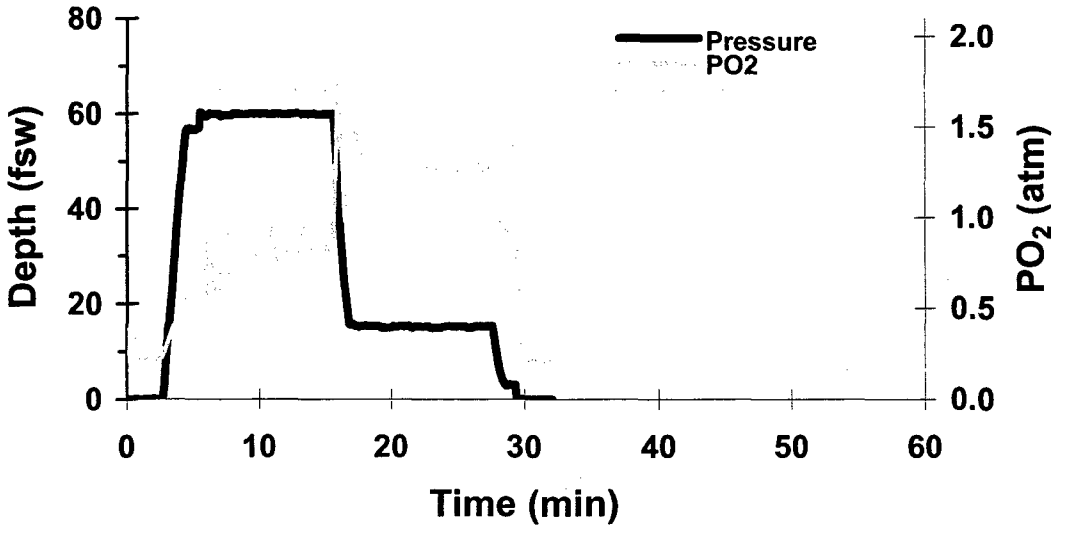
Dive 27. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



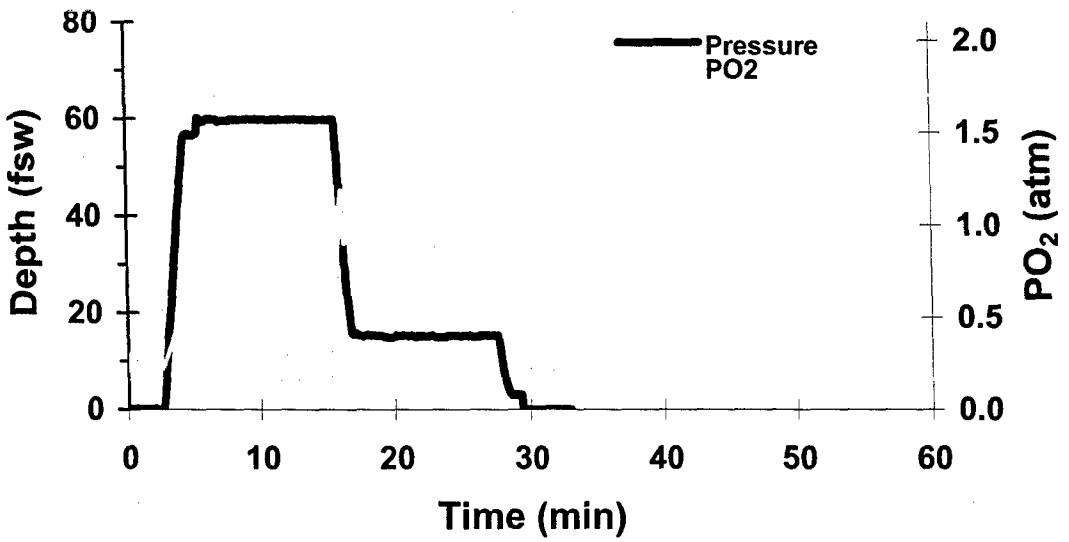
Dive 28. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



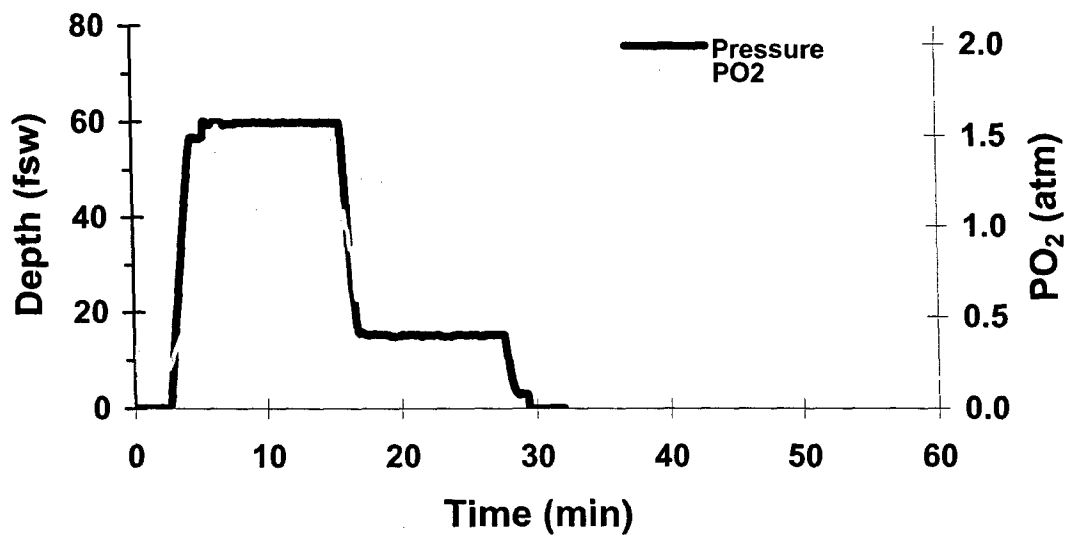
Dive 29. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



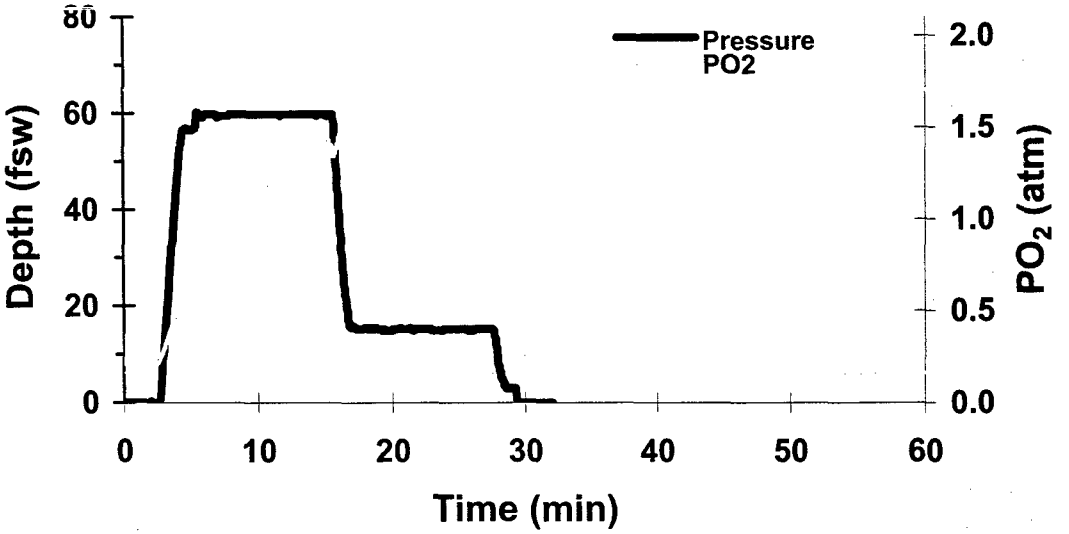
Dive 30. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



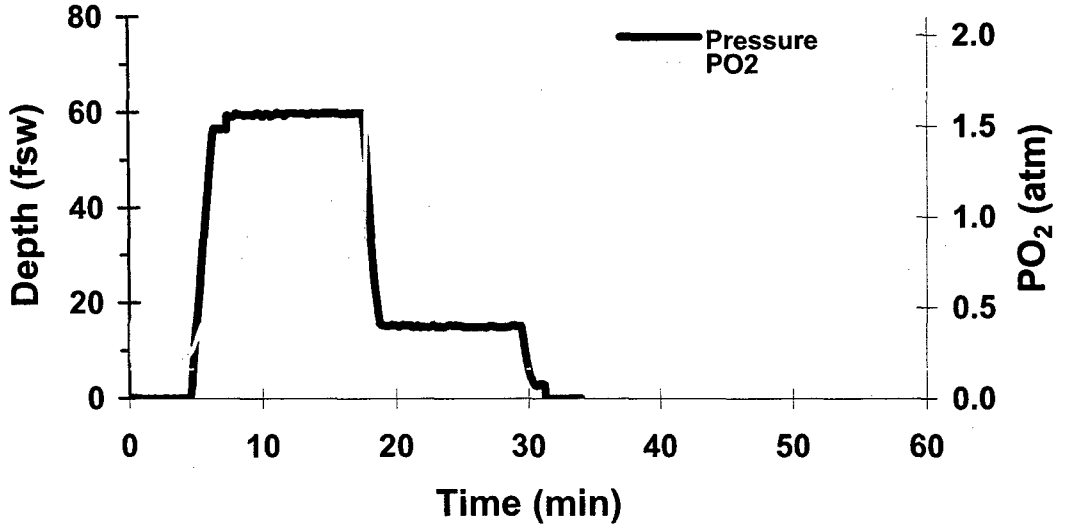
Dive 31. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. $PO_2 < PO_{2min}$ at O2 valve actuation. Dive completed without violating PO_2 safety criteria.



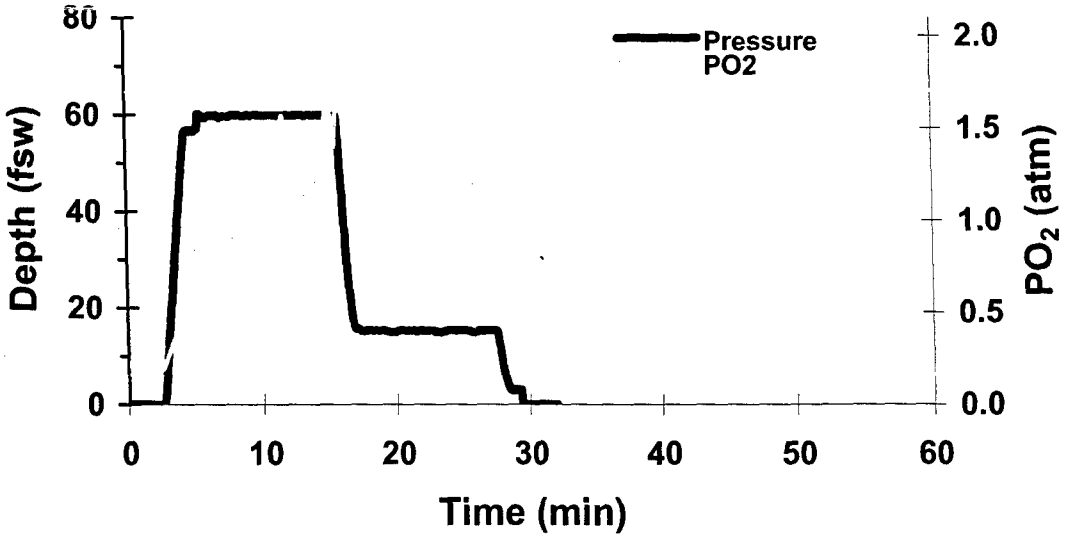
Dive 32. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



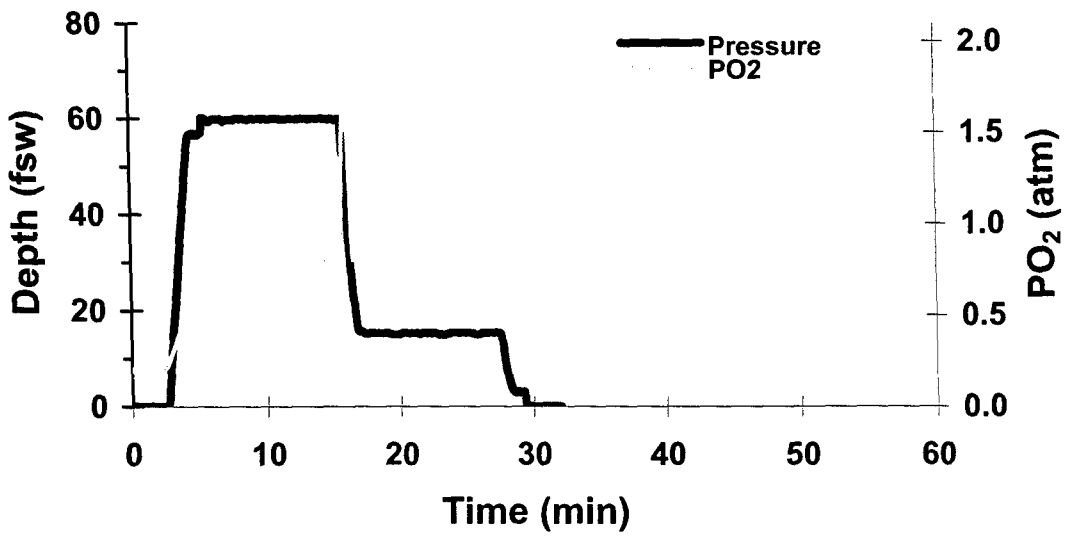
Dive 33. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



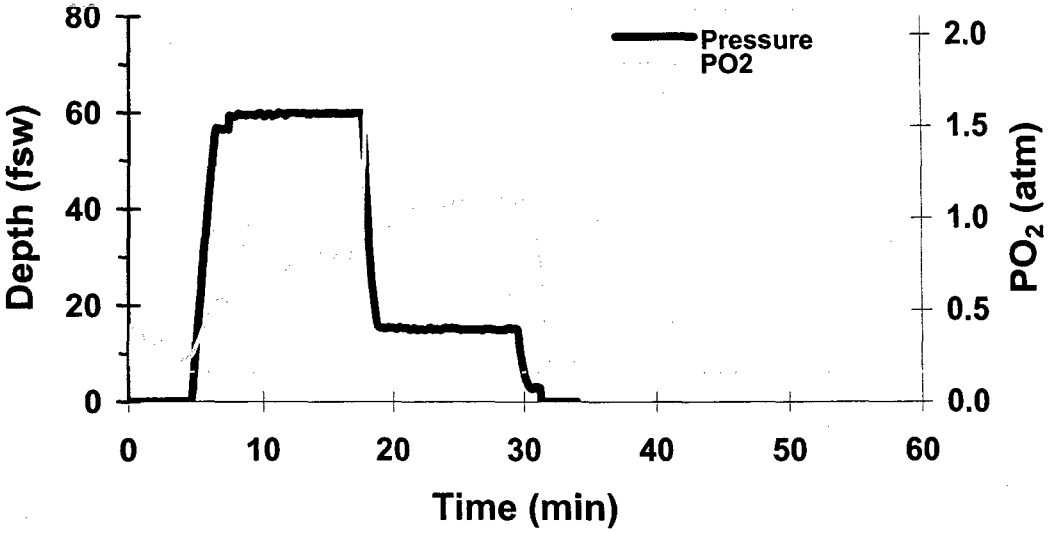
Dive 34. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



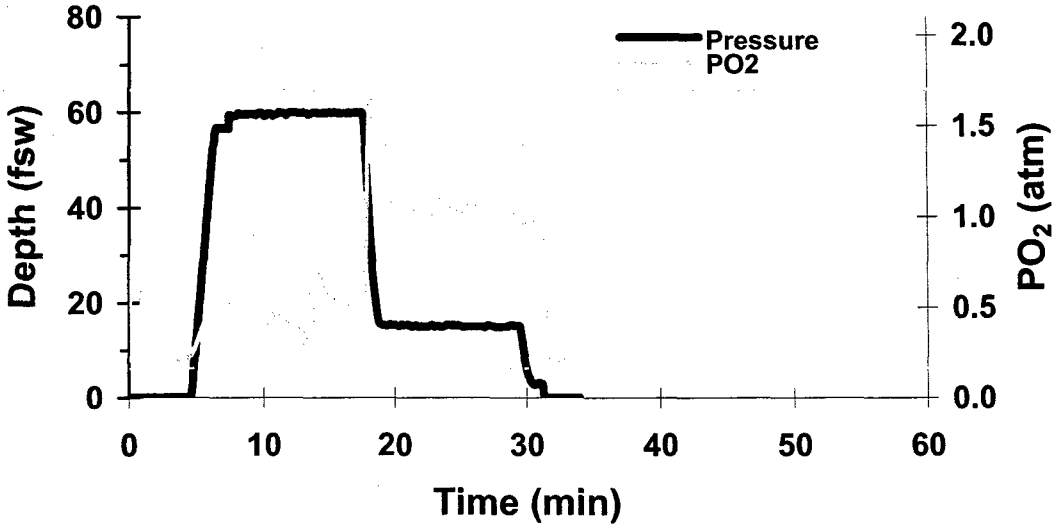
Dive 35. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



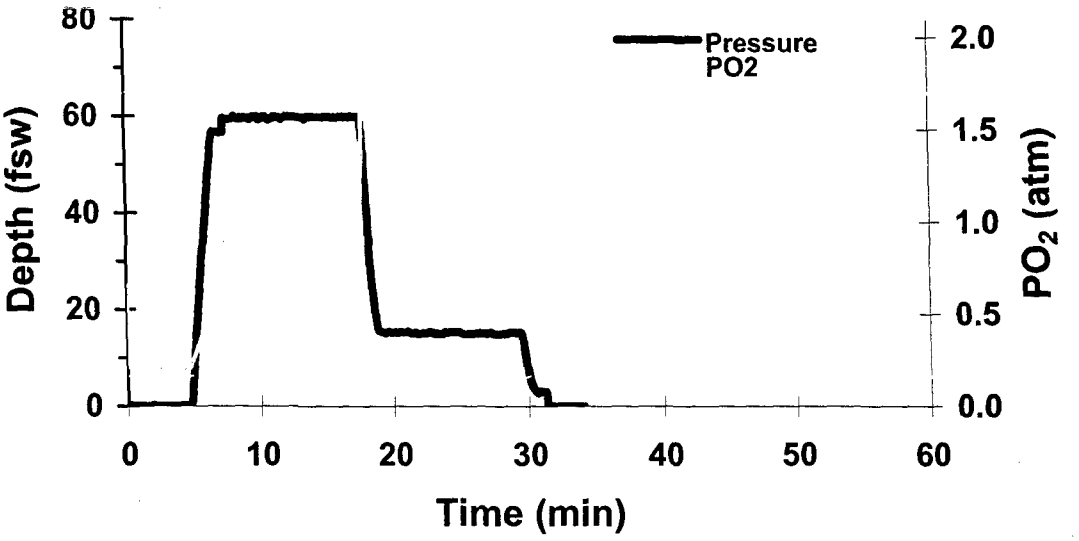
Dive 36. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



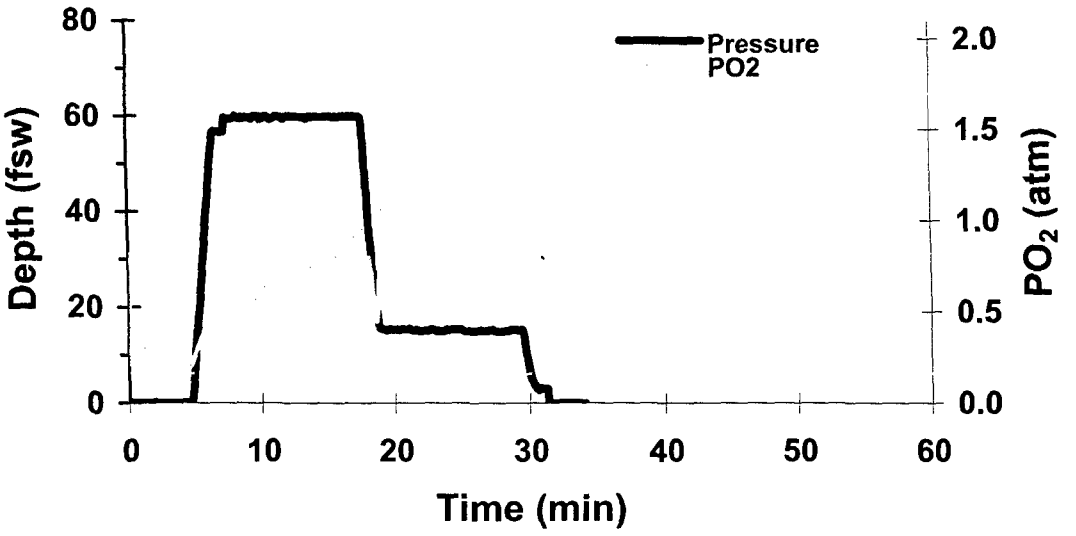
Dive 37. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



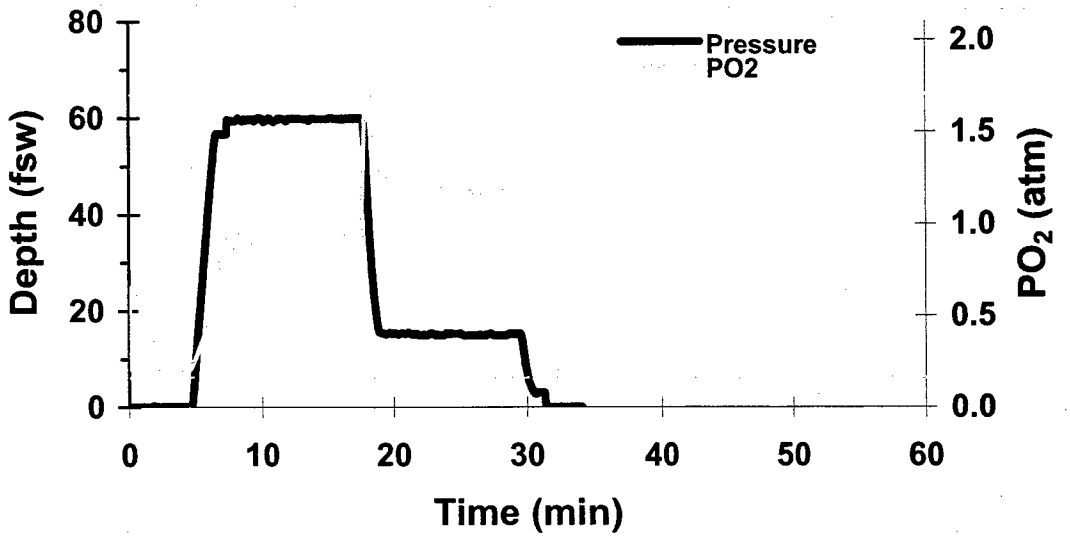
Dive 38. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



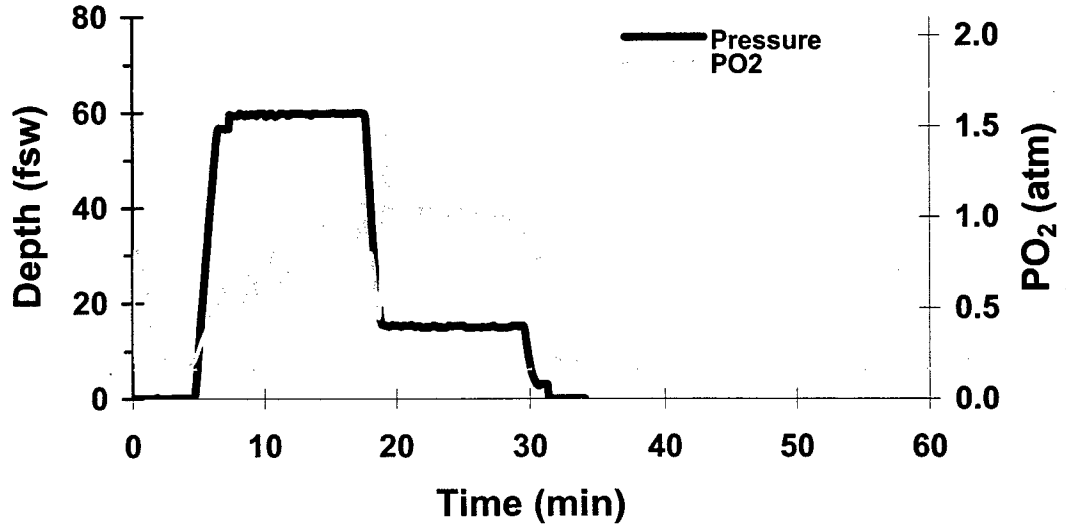
Dive 39. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



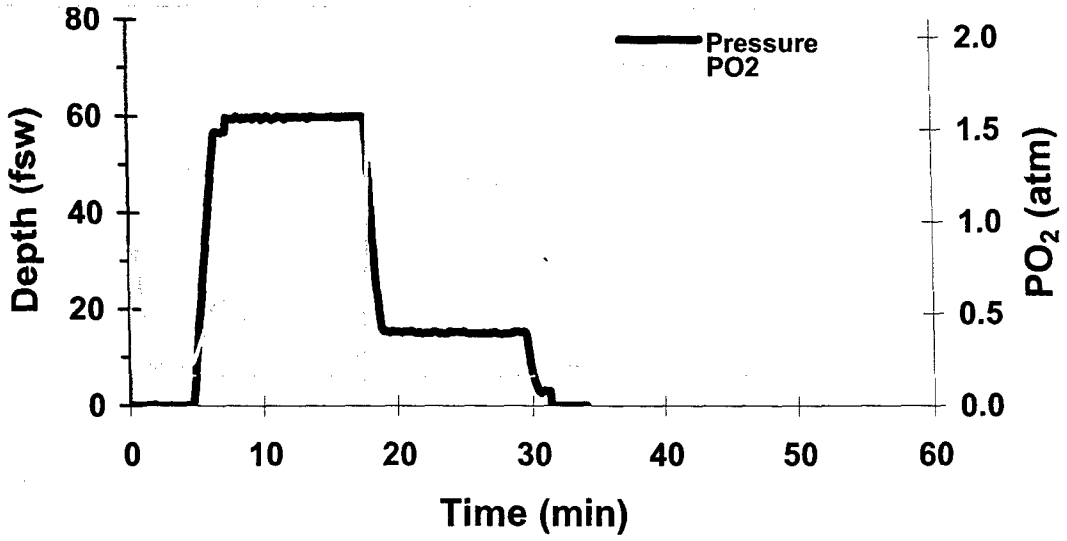
Dive 40. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



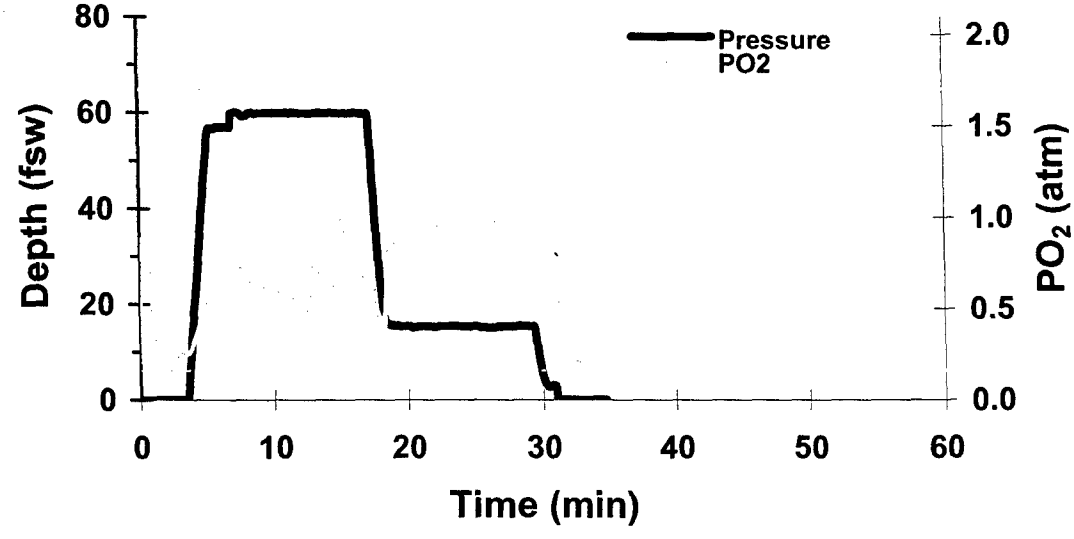
Dive 41. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



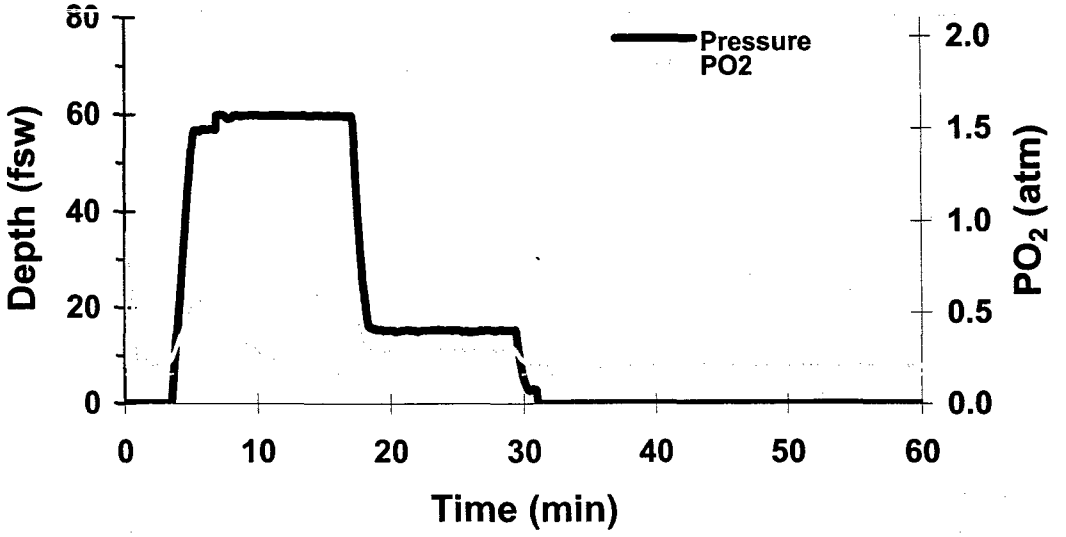
Dive 42. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



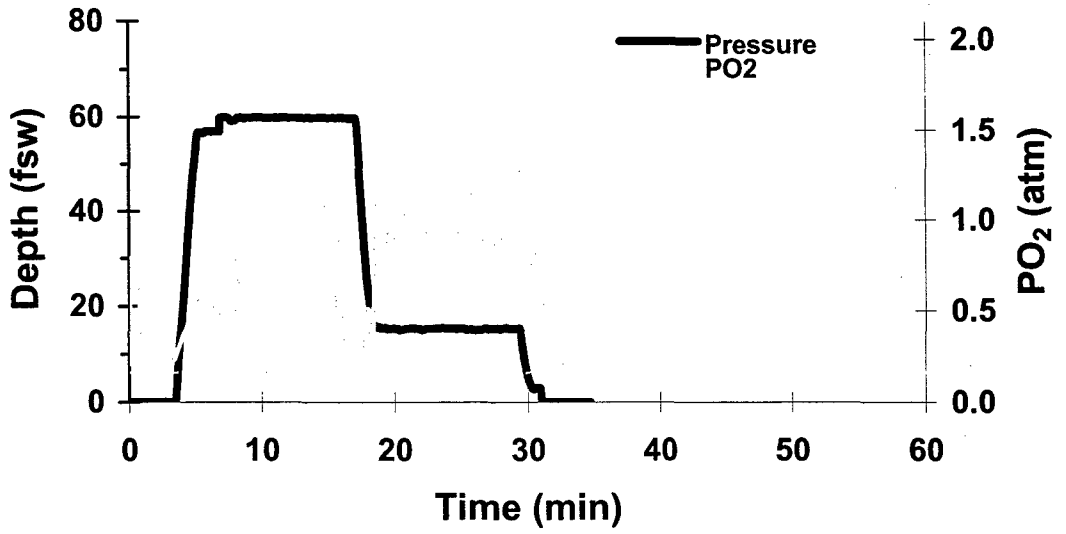
Dive 43. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. $PO_2 < PO_{2min}$ at O2 valve actuation. Dive completed without violating PO_2 safety criteria.



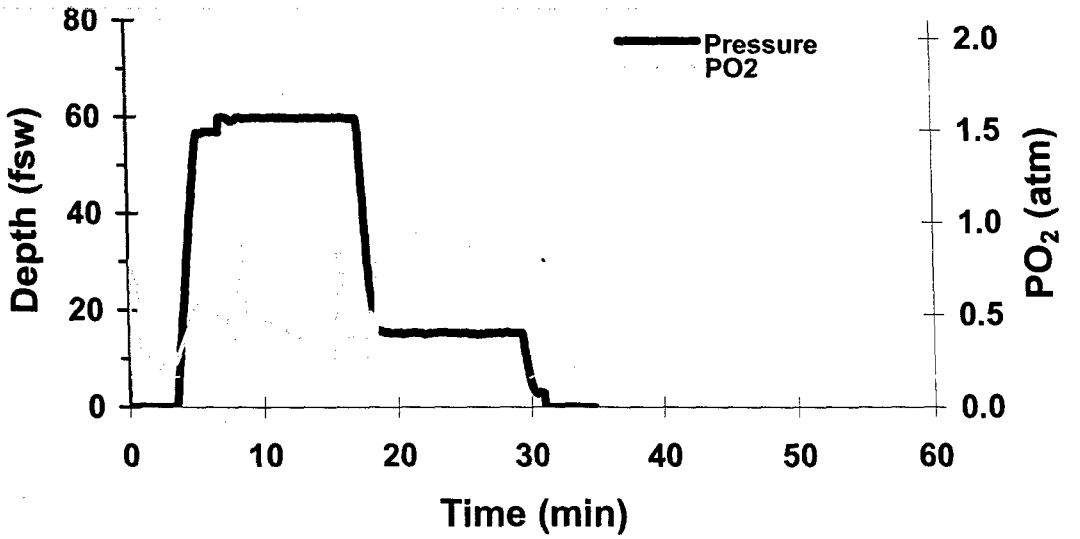
Dive 44. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



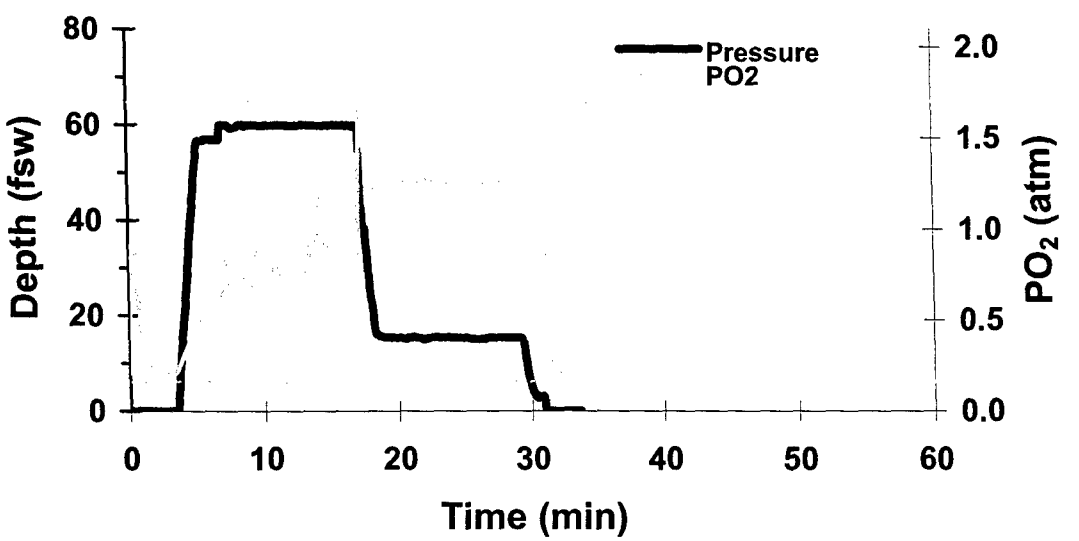
Dive 45. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Diver pulled; $PO_2 < PO_{2min}$ before ascent.



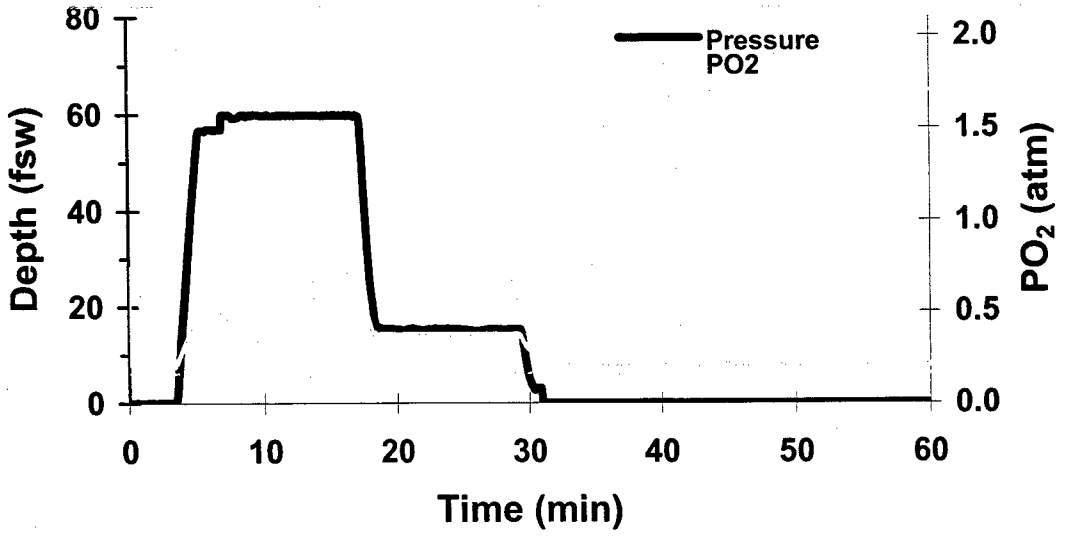
Dive 46. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



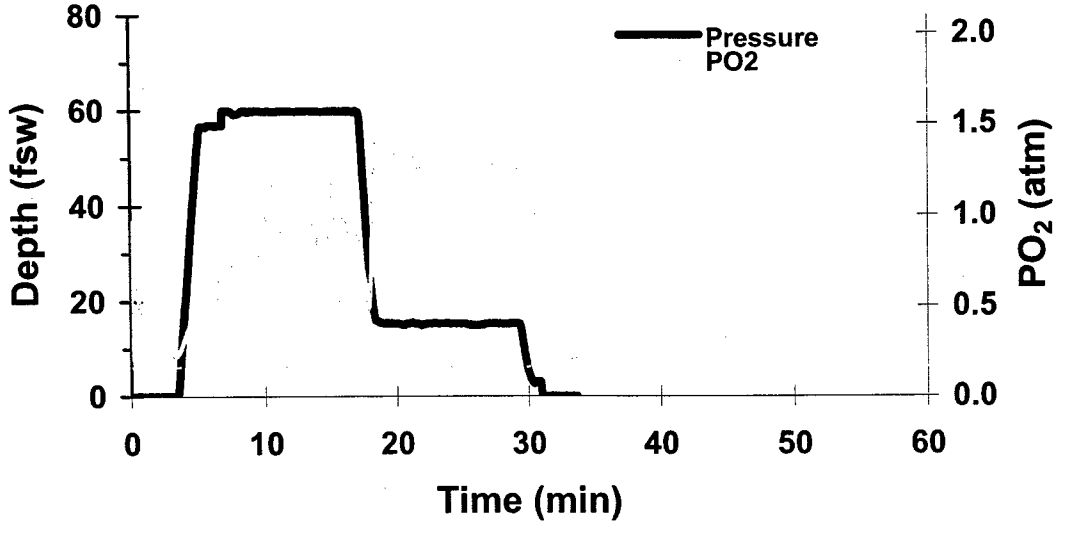
Dive 47. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. $PO_2 < PO_{2min}$ at O_2 valve actuations. Dive completed without violating PO_2 safety criteria.



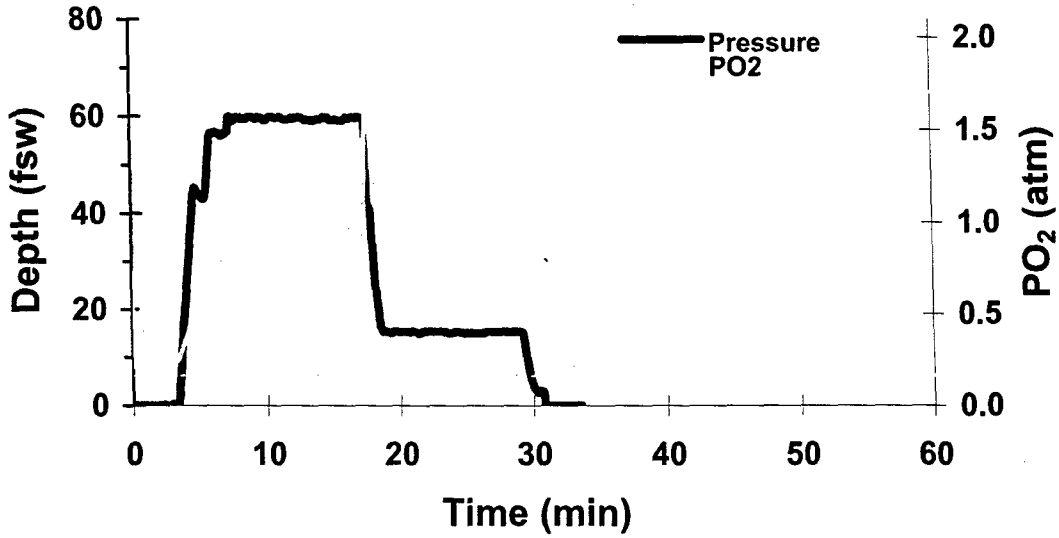
Dive 48. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



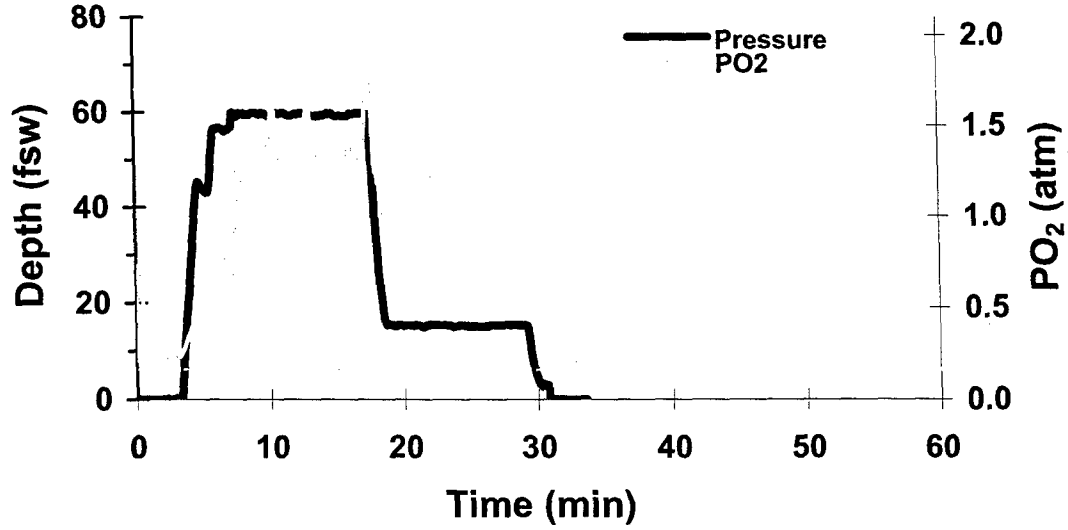
Dive 49. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Diver pulled; $PO_2 < PO_{2min}$ before ascent.



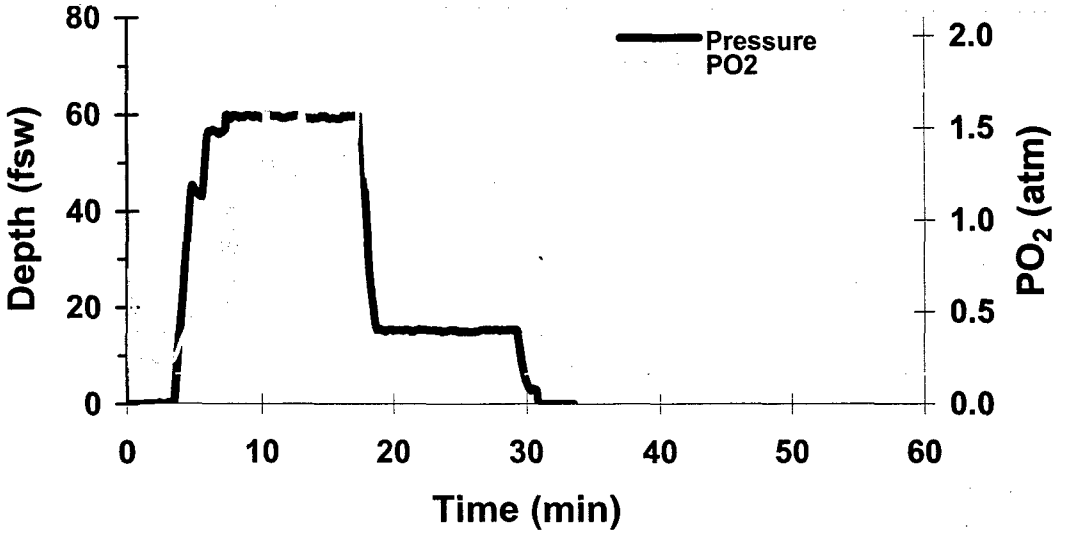
Dive 50. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



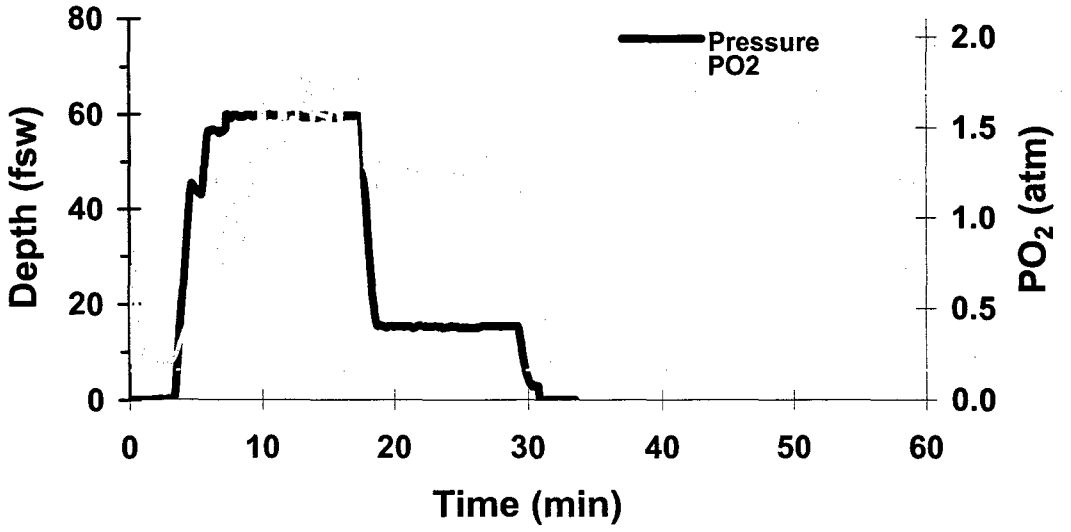
Dive 51. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



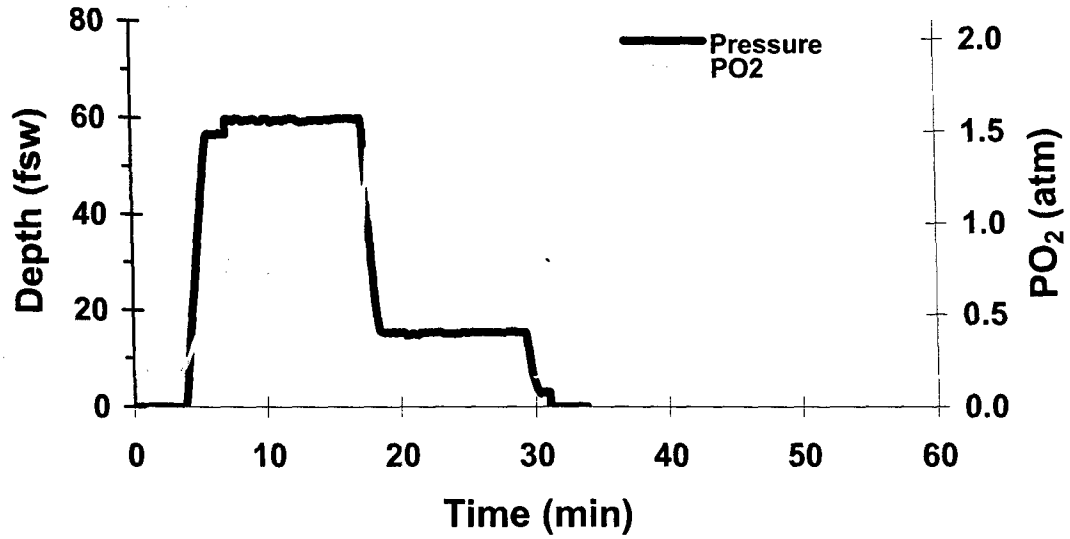
Dive 52. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



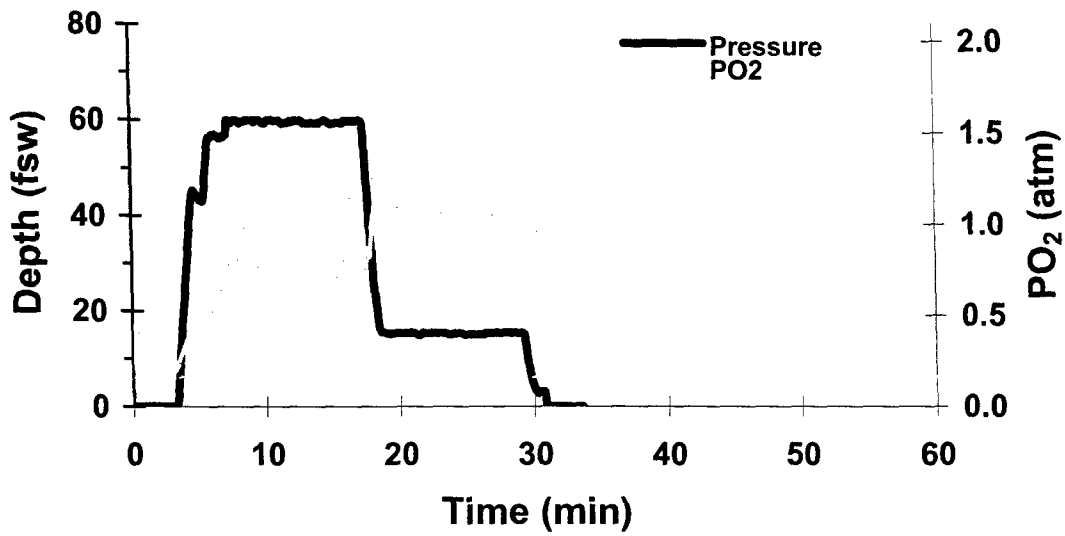
Dive 53. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



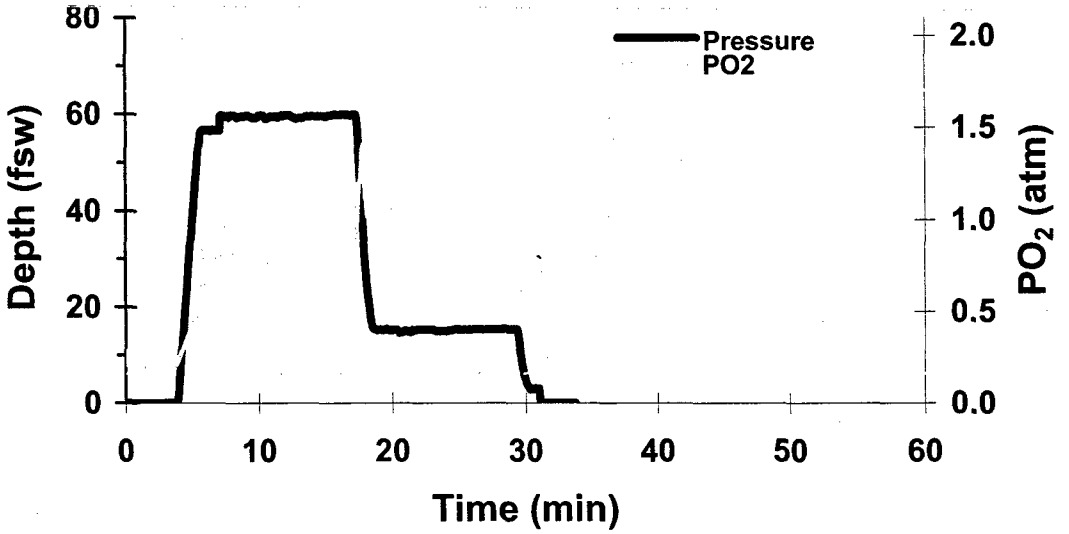
Dive 54. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



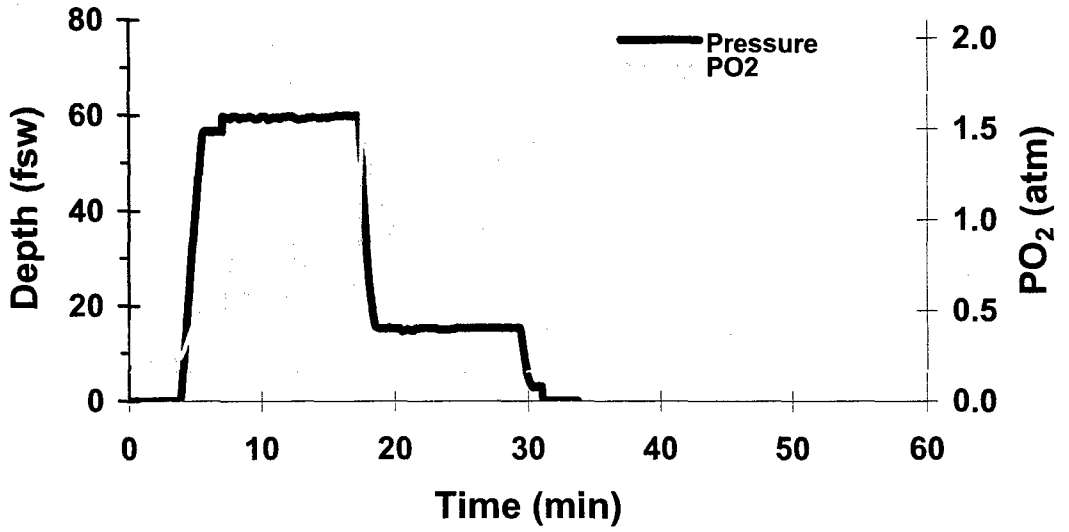
Dive 55. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



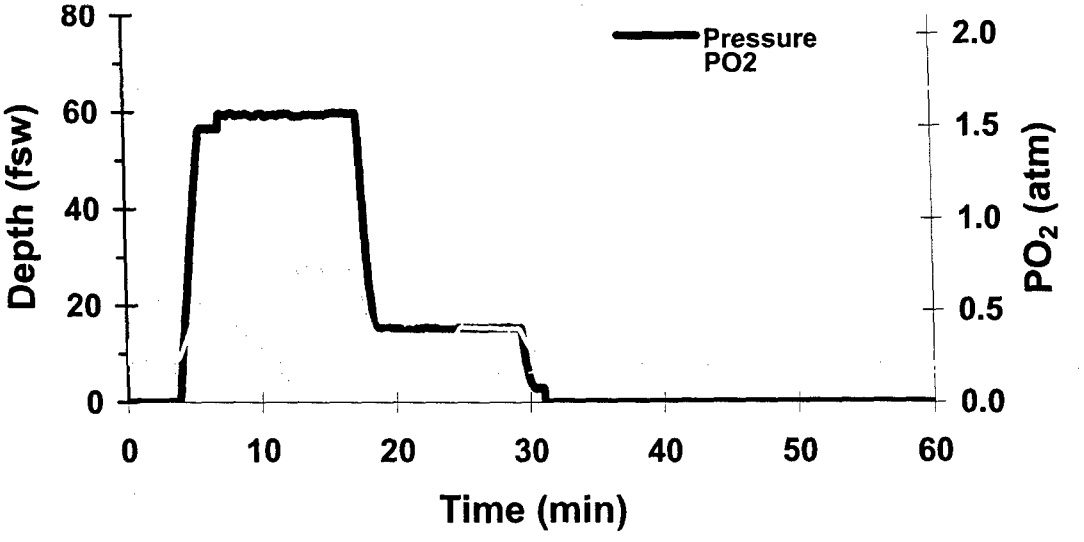
Dive 56. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



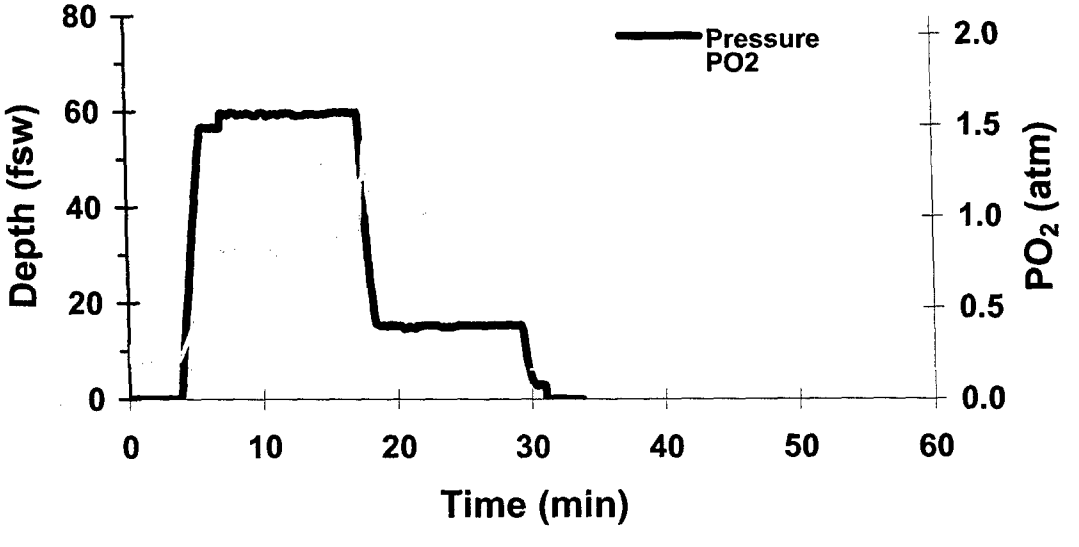
Dive 57. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



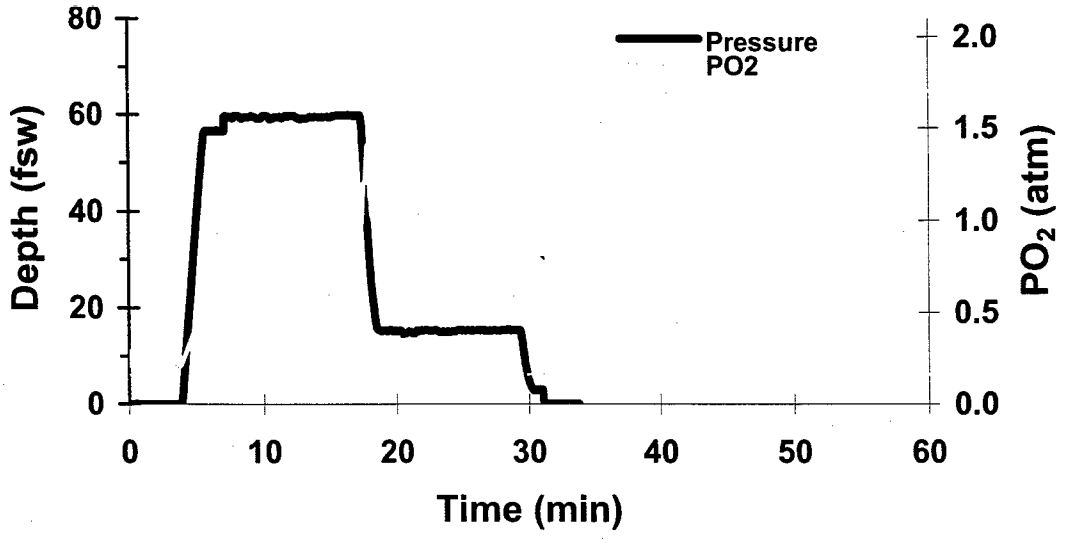
Dive 58. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



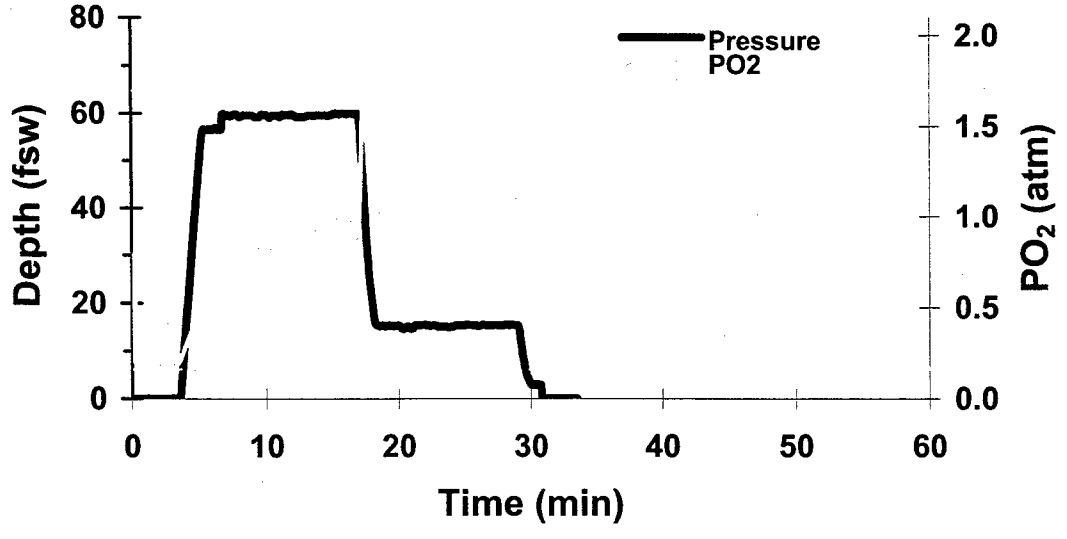
Dive 59. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Diver pulled; $PO_2 < PO_{2min}$ before ascent.



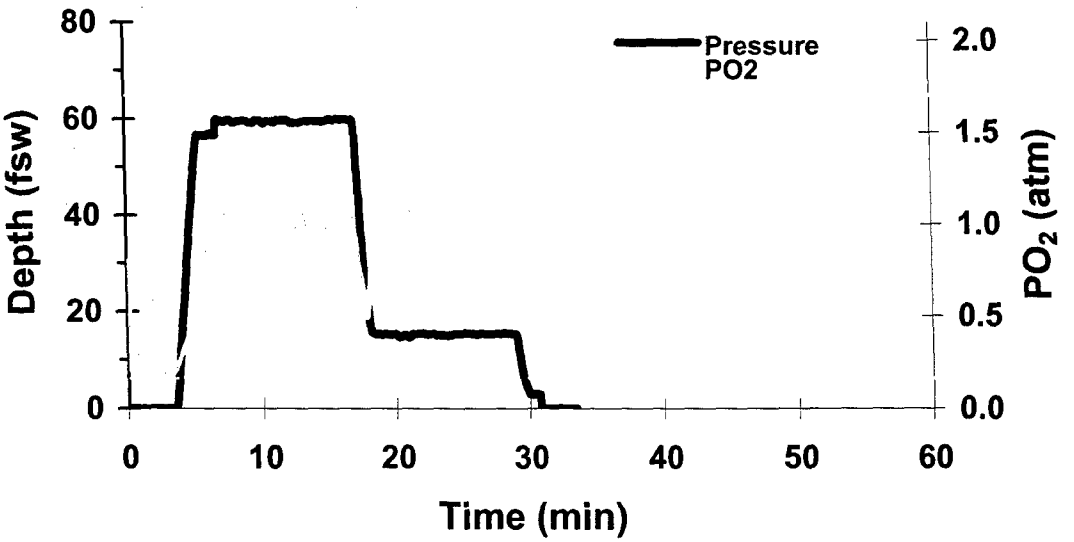
Dive 60. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



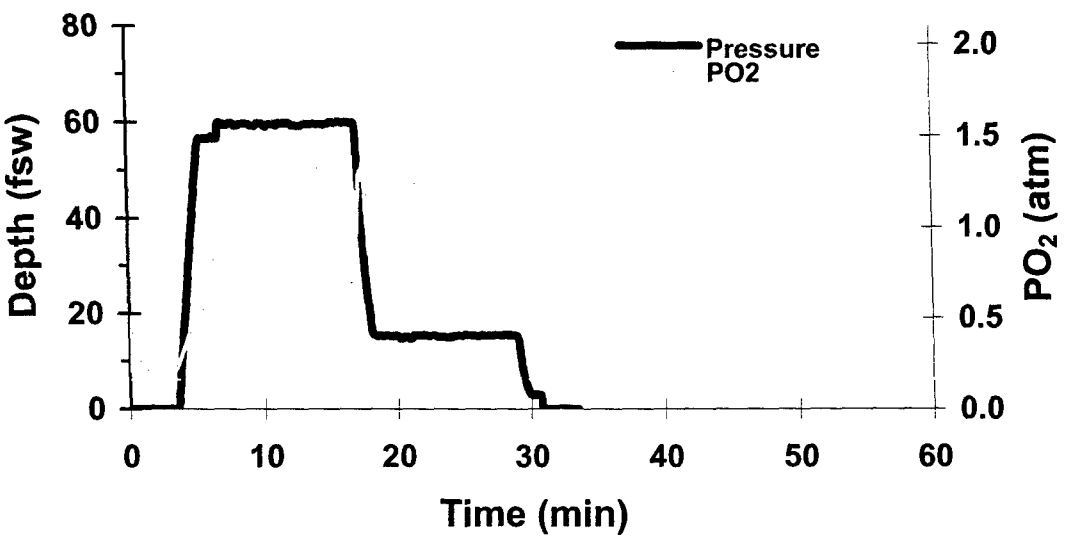
Dive 61. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



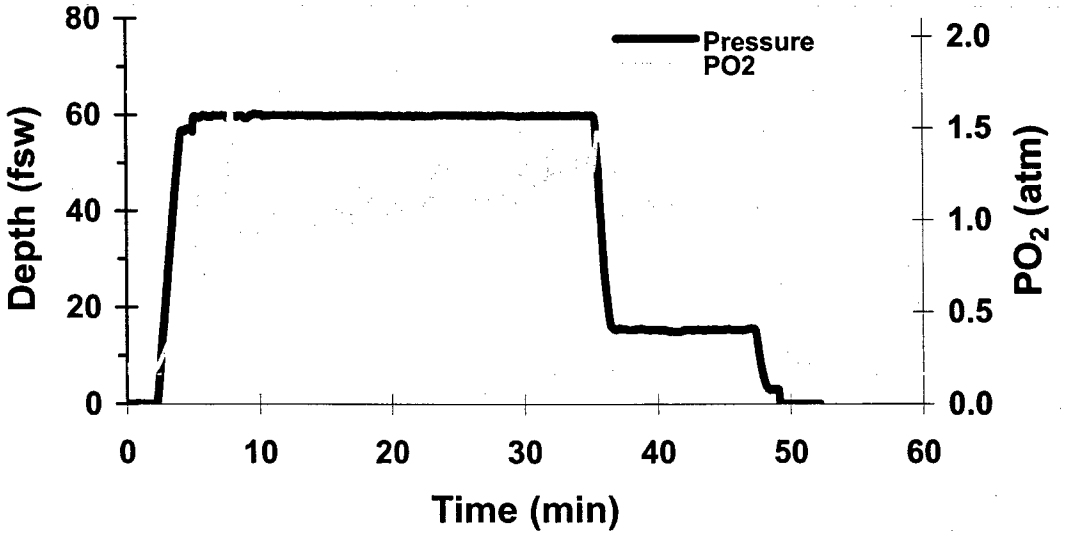
Dive 62. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



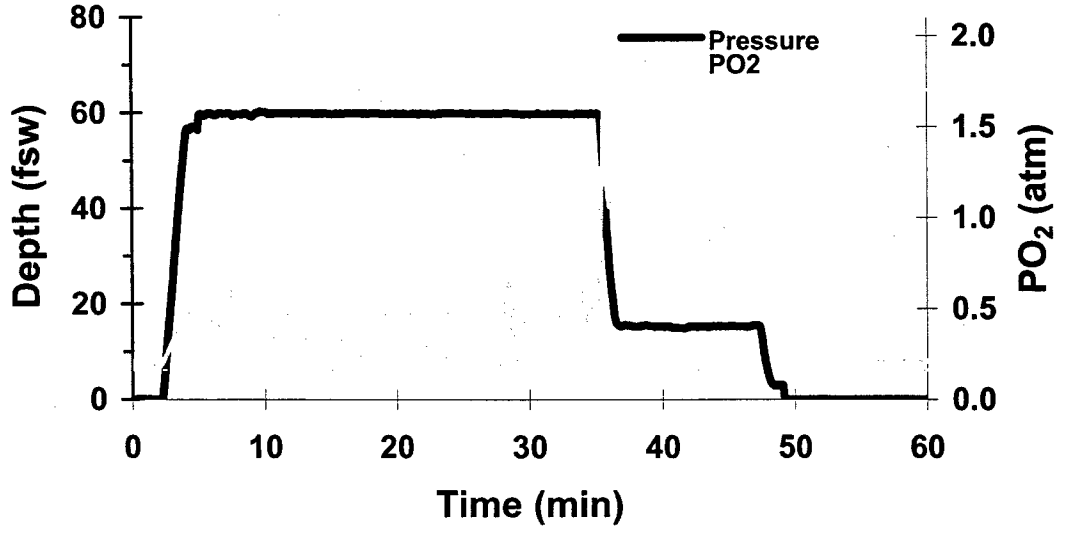
Dive 63. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



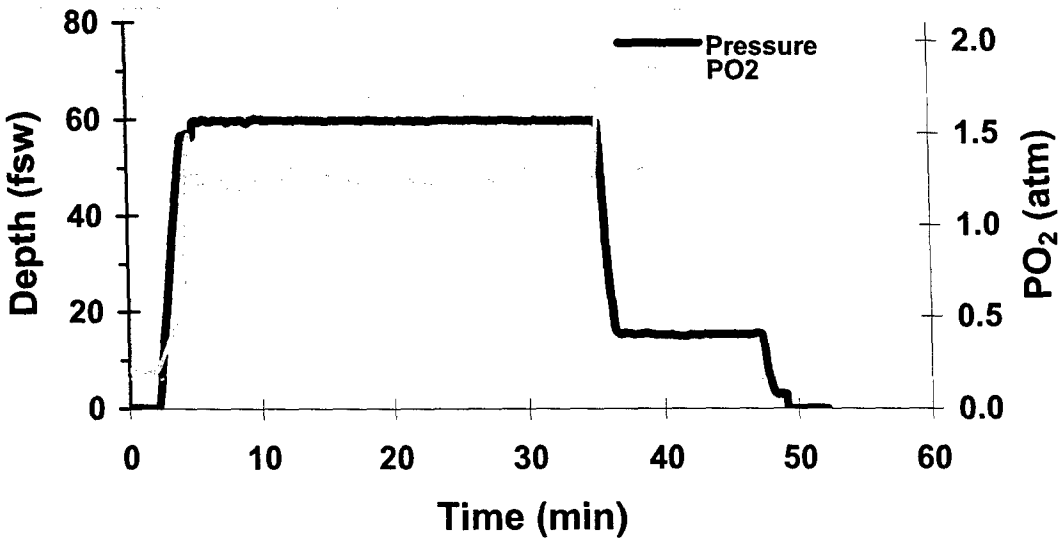
Dive 64. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



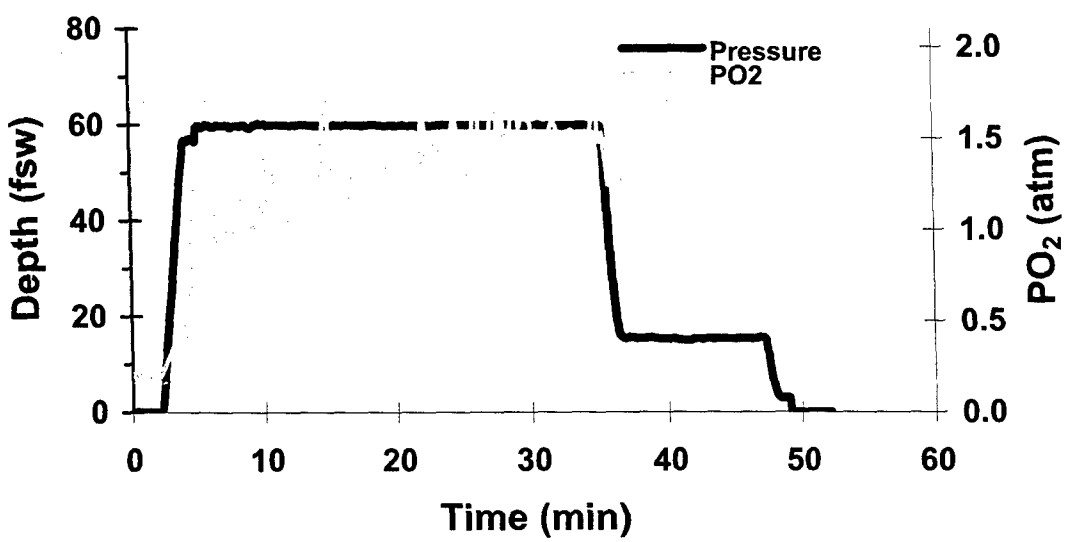
Dive 65. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



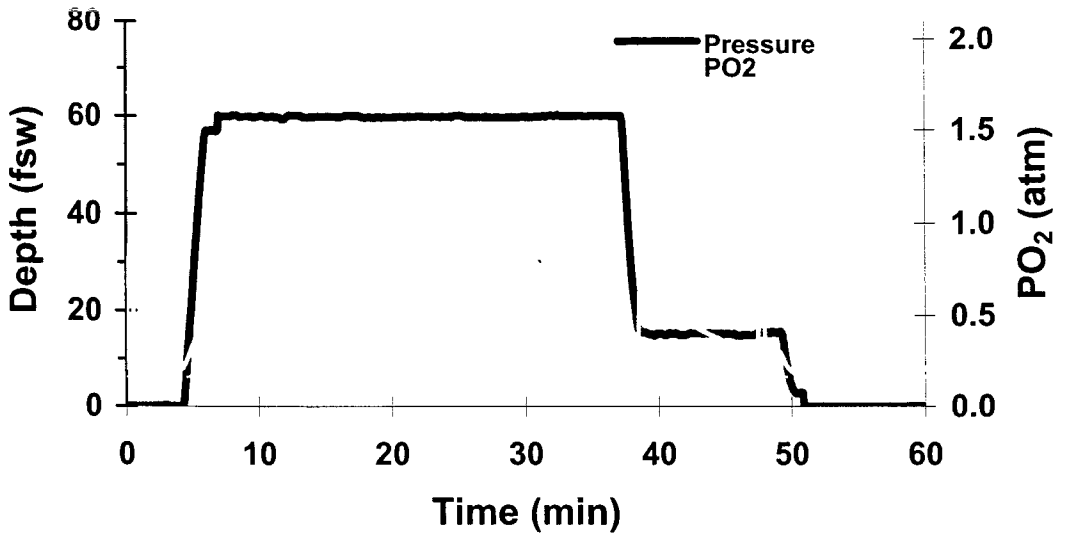
Dive 66. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. $PO_2 < PO_{2min}$ during O2 valve actuations. Dive completed without violating PO_2 safety criteria.



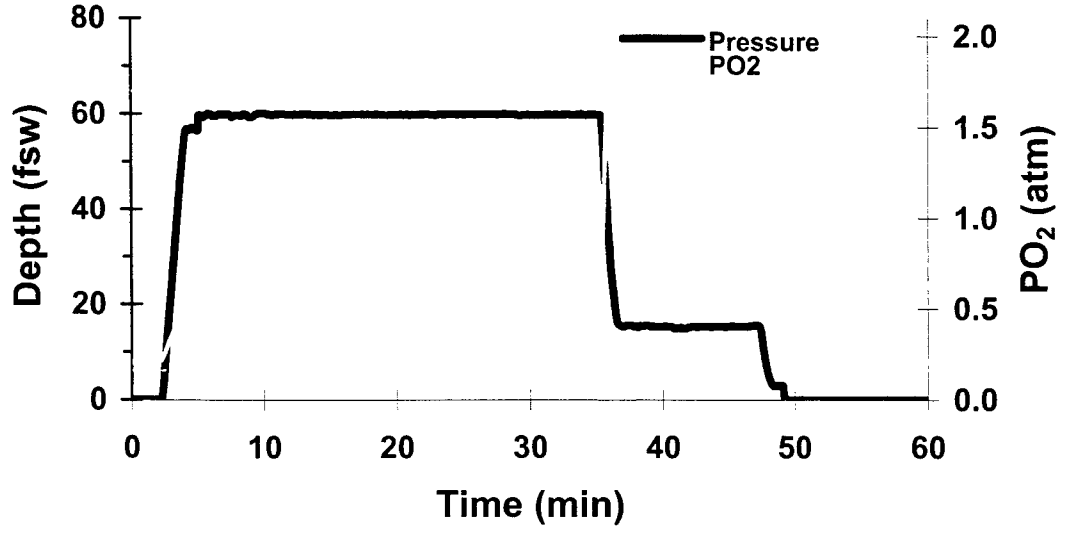
Dive 67. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



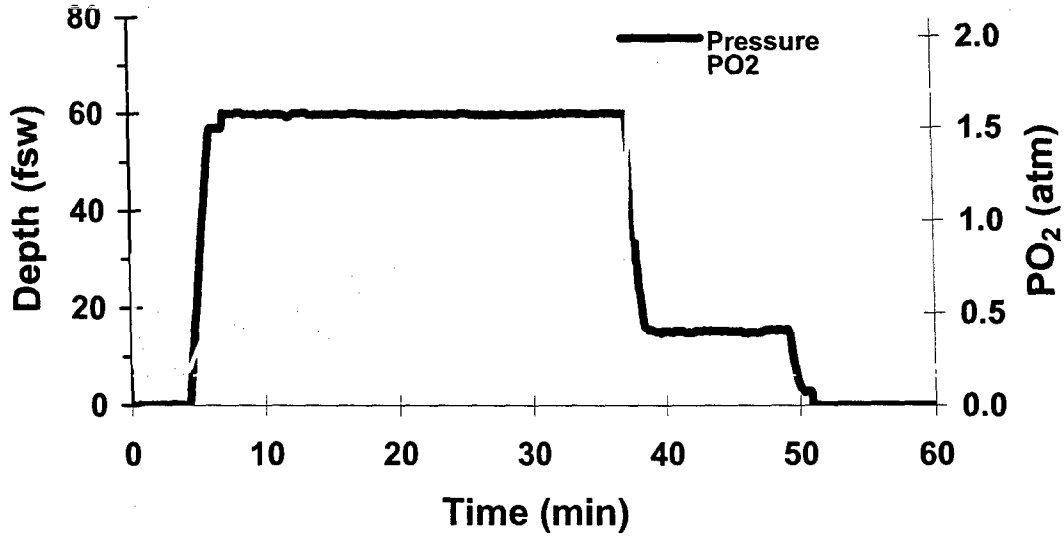
Dive 68. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



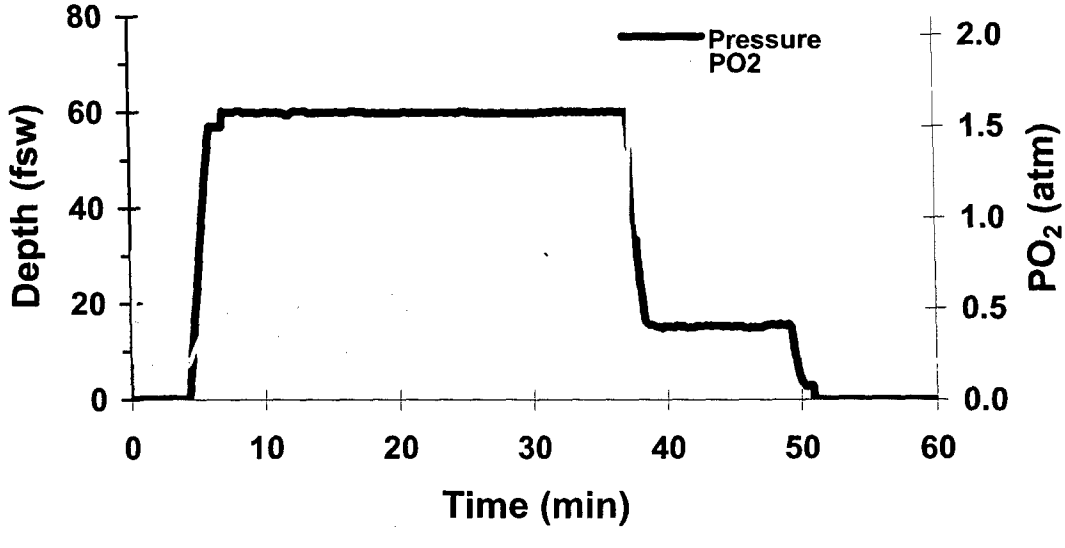
Dive 69. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. $PO_2 < PO_{2min}$ at O_2 valve actuation. O_2 bottle closed until 10:04 of dive. Diver informed over coms. Dive completed without violating PO_2 safety criteria. Not included in data analyses.



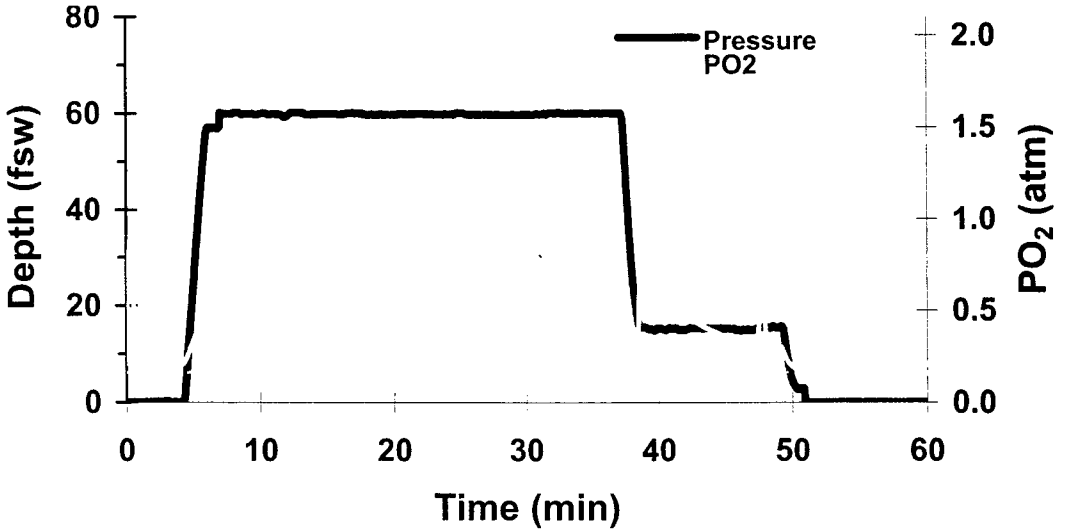
Dive 70. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



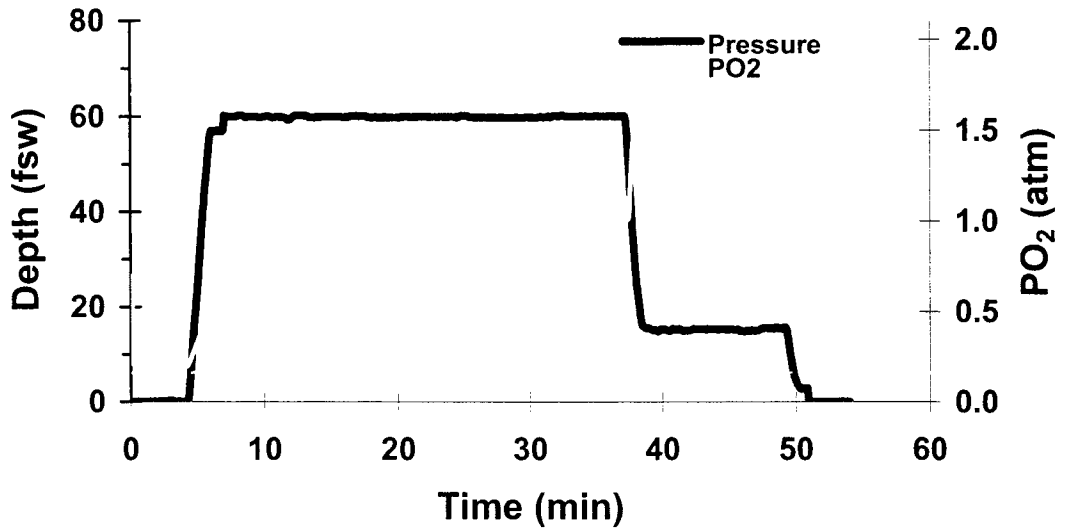
Dive 71. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



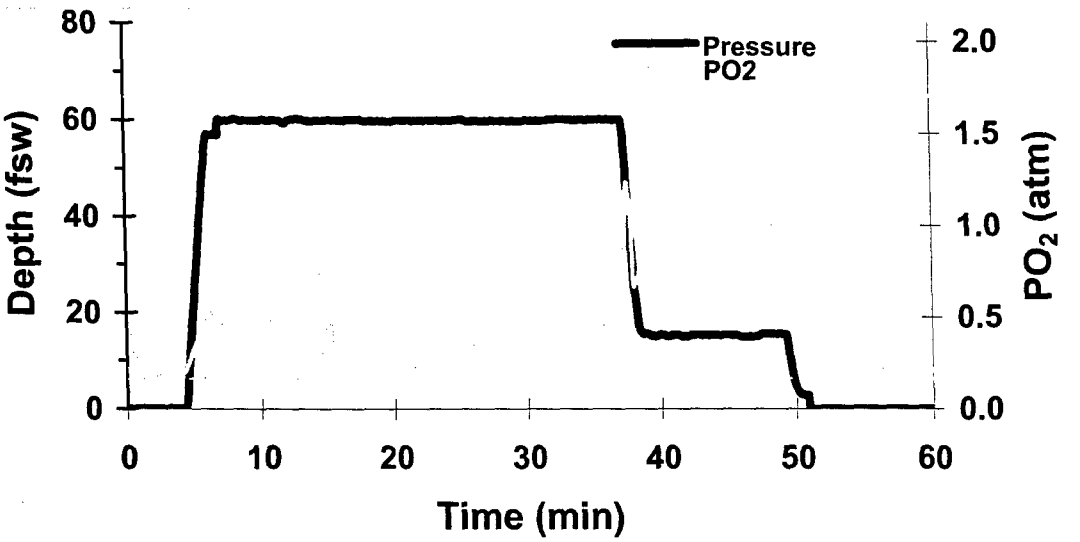
Dive 72. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



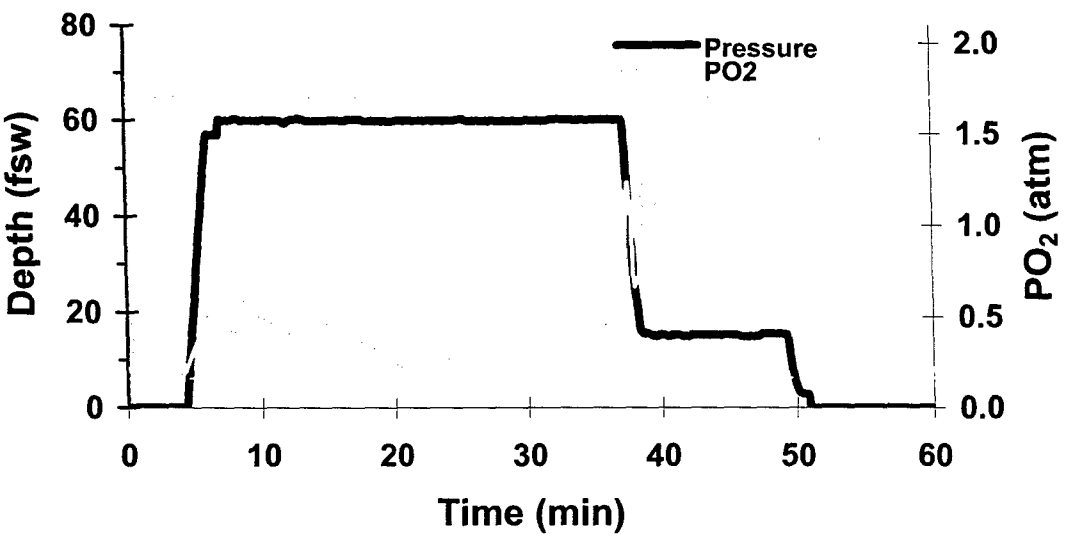
Dive 73. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. $PO_2 < PO_{2min}$ at O_2 valve actuations. Dive completed without violating PO_2 safety criteria.



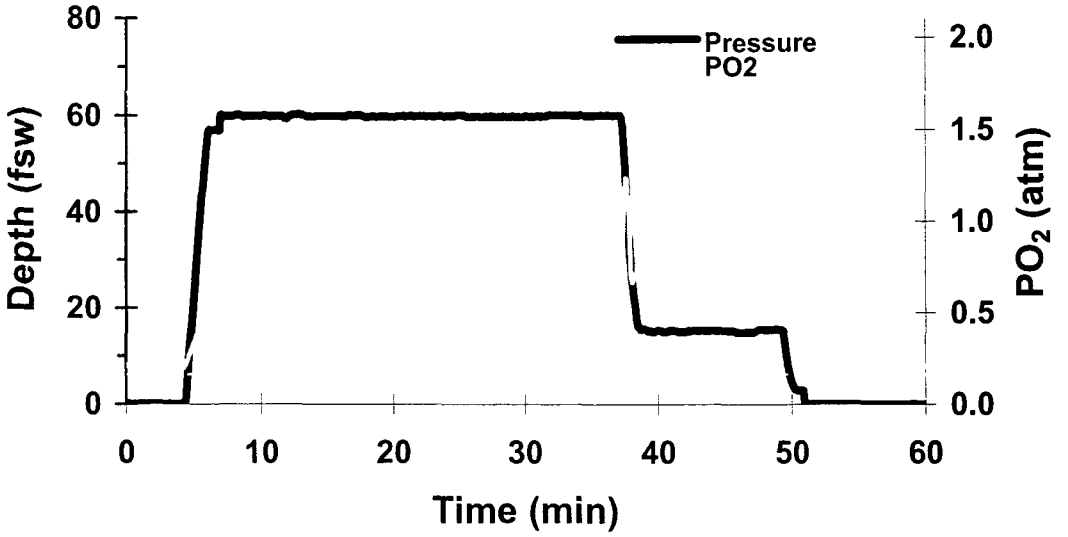
Dive 74. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



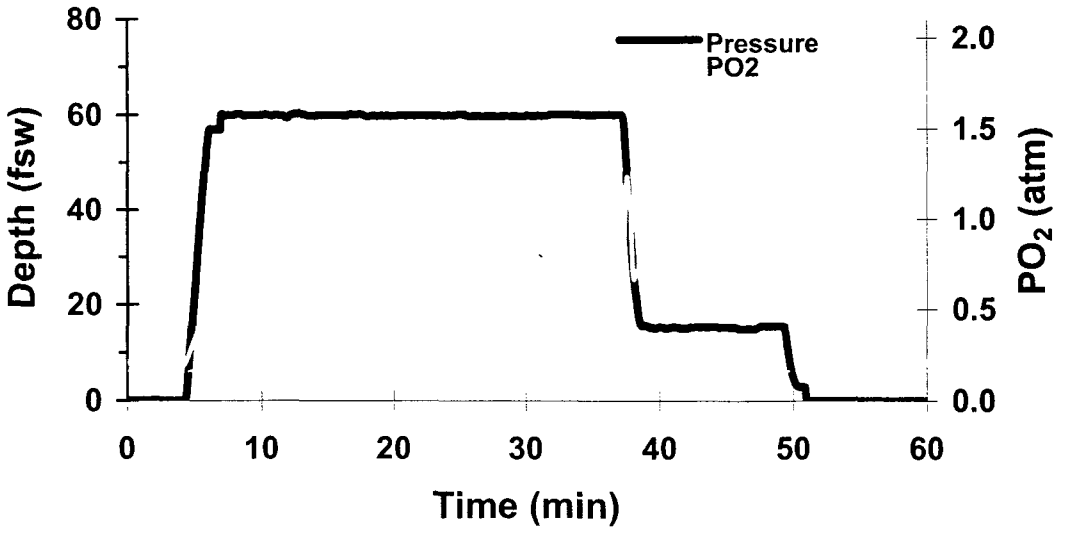
Dive 75. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



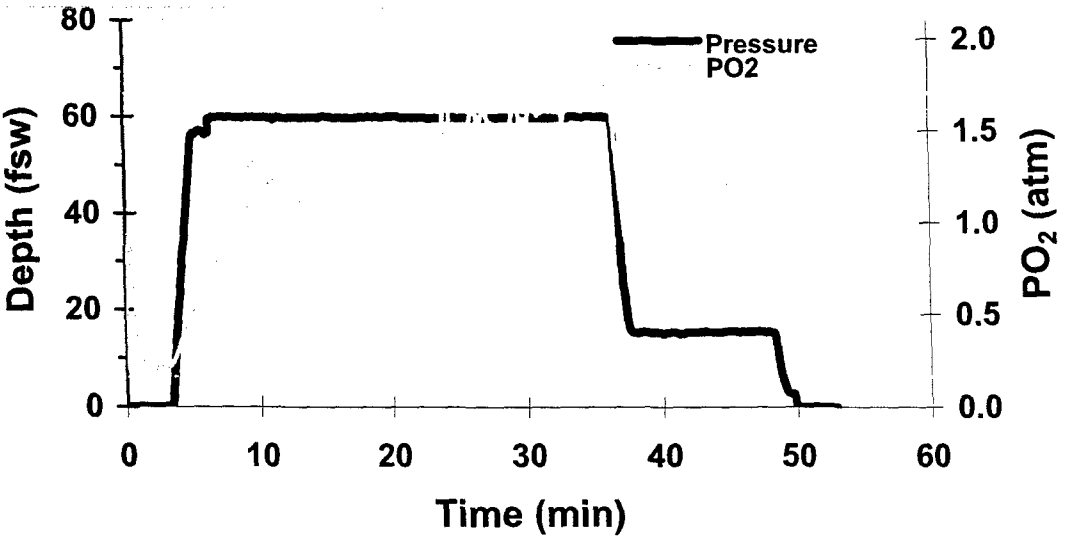
Dive 76. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



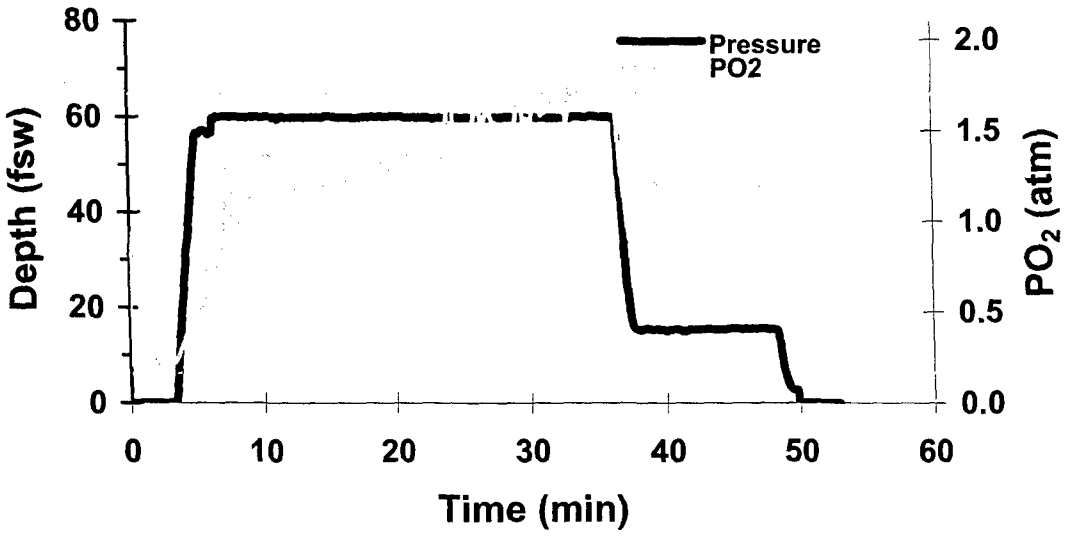
Dive 77. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



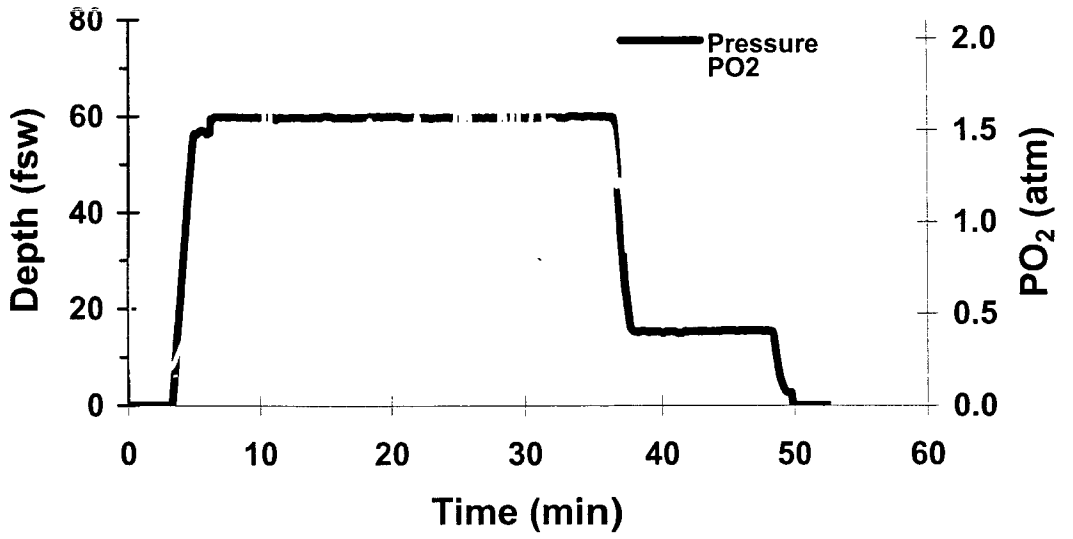
Dive 78. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



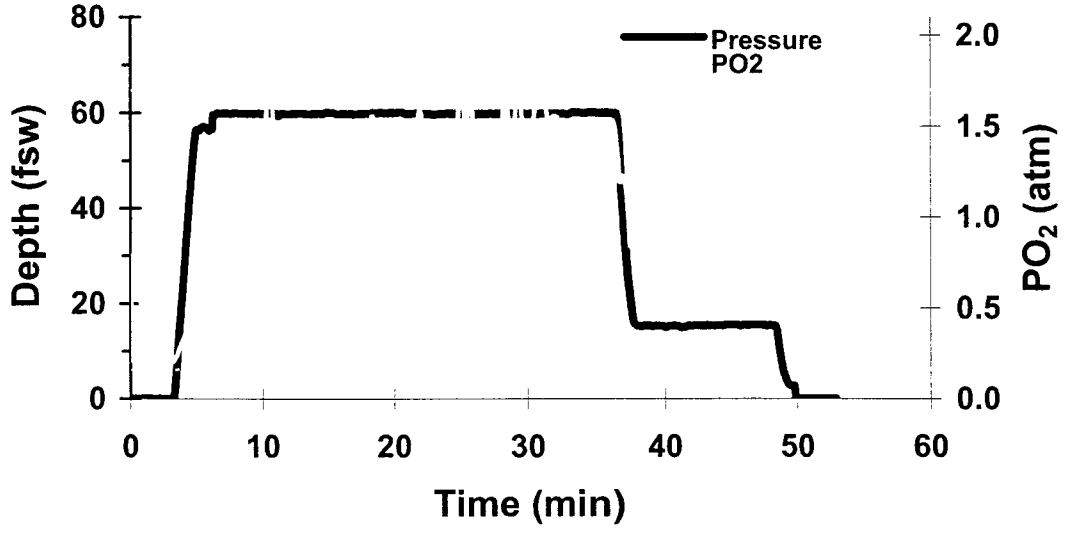
Dive 79. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



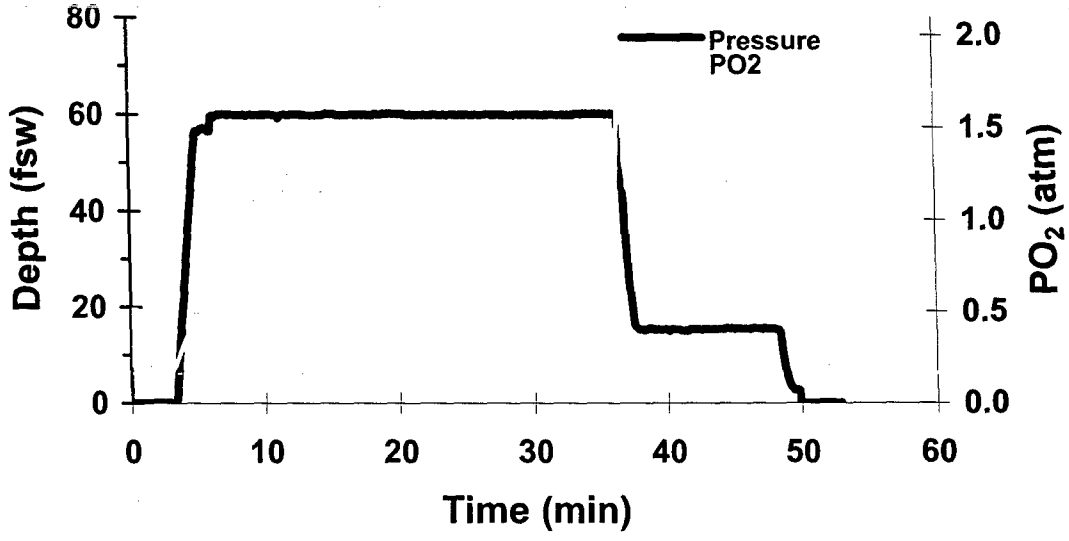
Dive 80. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



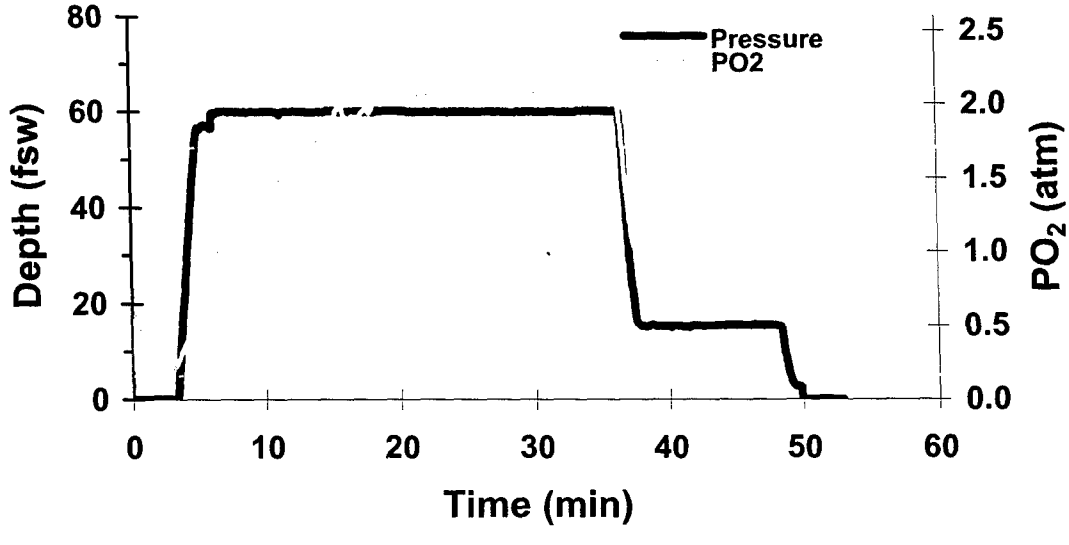
Dive 81. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



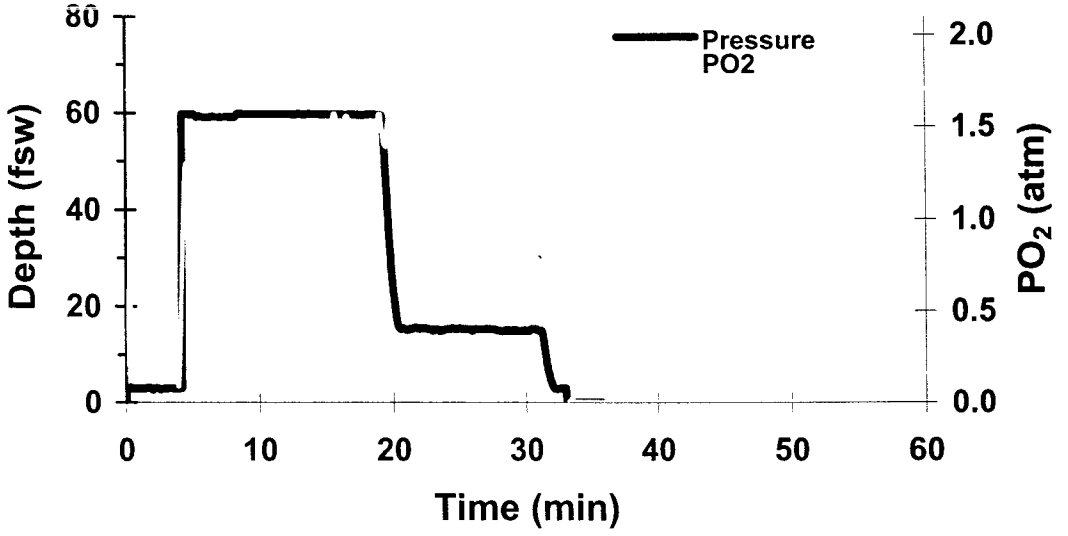
Dive 82. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



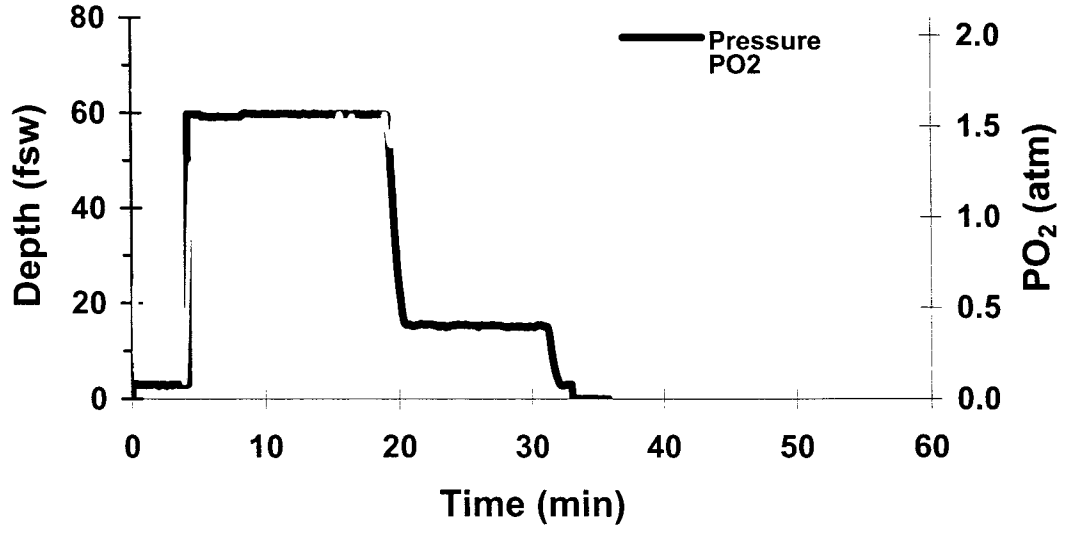
Dive 83. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



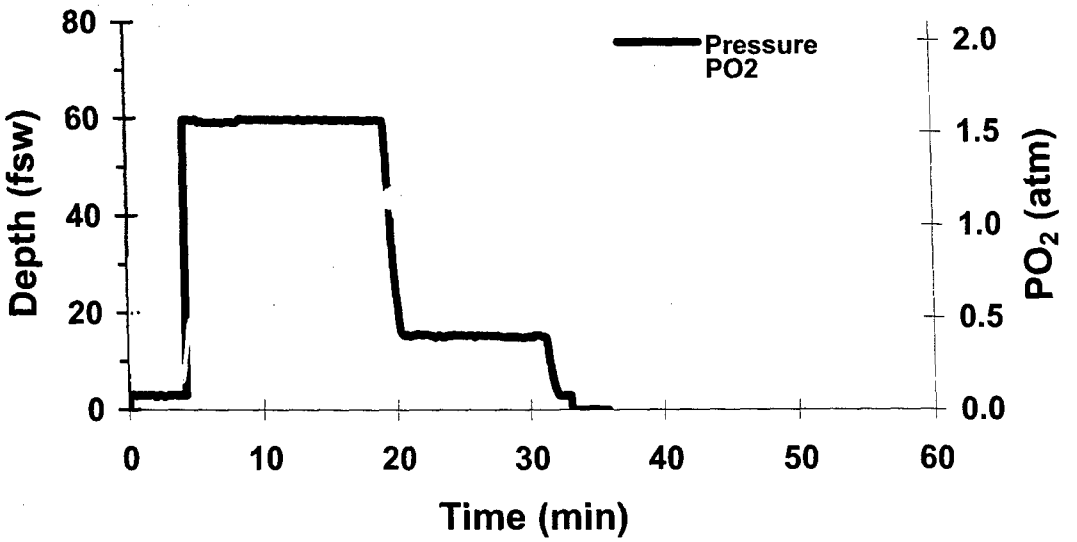
Dive 84. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Diver pulled; $PO_2 > PO_{2max}$ for at least 10 minutes before ascent (scale modified to capture elevated data points).



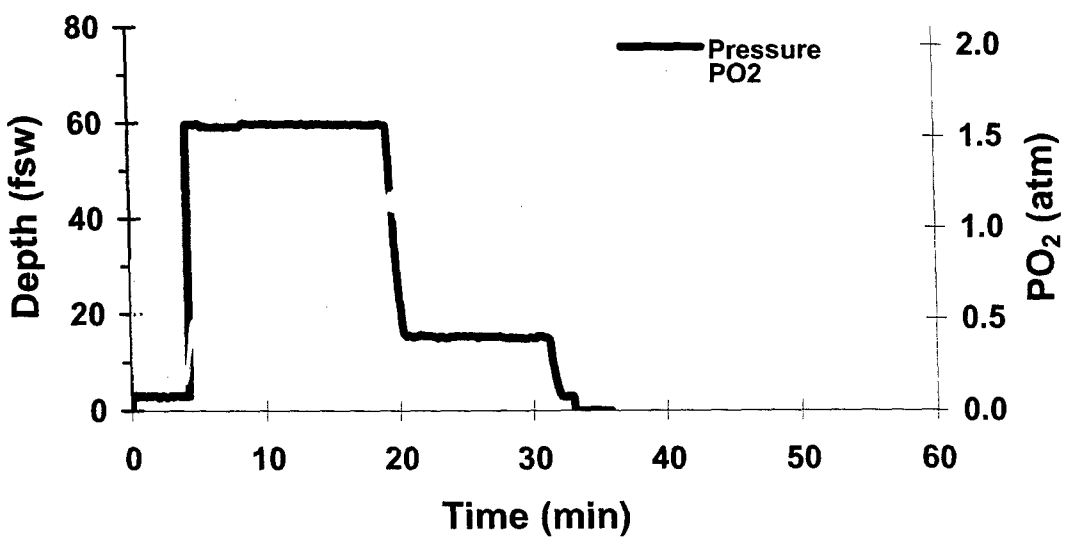
Dive 85. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



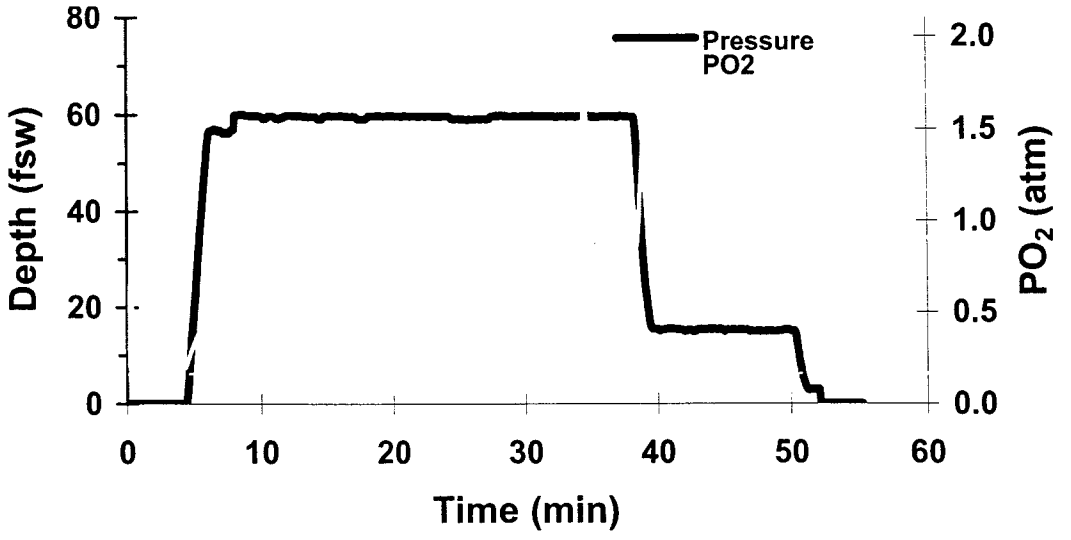
Dive 86. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Data lost before ascent. Dive completed without violating PO_2 safety criteria. Pre-ascent delay not included in data analysis.



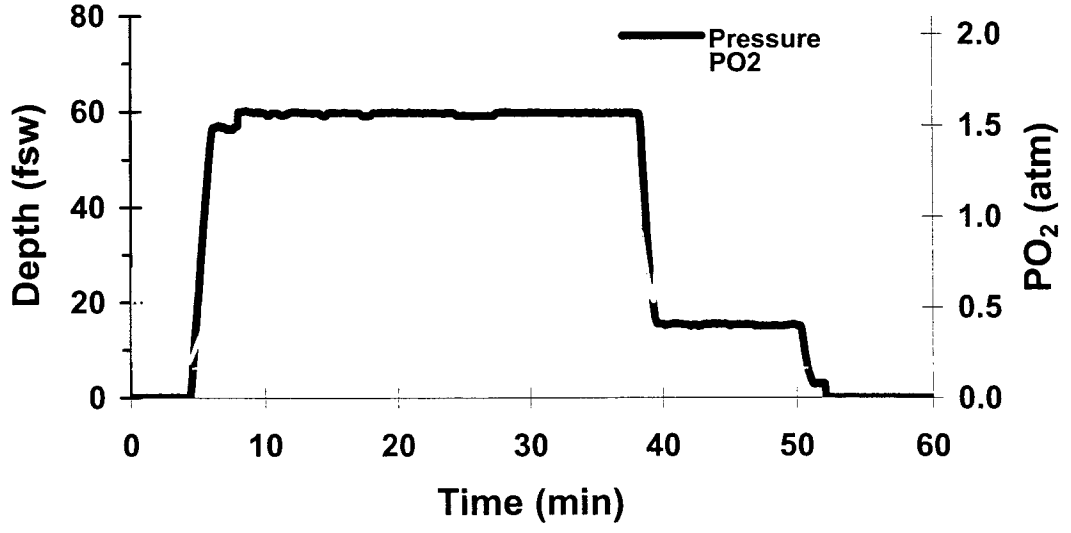
Dive 87. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Data lost before ascent. Dive completed without violating PO_2 safety criteria. Pre-ascent delay not included in data analysis.



Dive 88. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Data lost before ascent. Dive completed without violating PO_2 safety criteria. Pre-ascent delay not included in data analysis.



Dive 91. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Dive completed without violating PO_2 safety criteria.



Dive 92. Dashed lines indicate PO_{2min} (0.16 ATM) and PO_{2max} (1.17 ATM) markers. Single $PO_2 < PO_{2min}$ at O2 valve actuation. Dive completed without violating PO_2 safety criteria.

Appendix B: Dive and PO_2 Summary Data

					RB thru Procedure			Preascent Delay			Ascent	
Dive	Depth (fsw)	Descent Rate (fsw/min)	BT (min)	Total Dive Time (min)	PO_2 MIN (atm)	PO_2 MAX (atm)	PO_2 TWA (atm)	PO_2 MIN (atm)	PO_2 MAX (atm)	PO_2 TWA (atm)	PO_2 MIN (atm)	PO_2 MAX (atm)
1	60.5	33.60	5.83	19.60	0.44	0.56	0.51	0.32	0.79	0.58	0.36	1.90
2	60.5	33.60	5.83	19.60	0.43	0.55	0.50	0.38	0.43	0.41	0.14	0.38
3	60.5	33.60	5.83	19.60	0.45	1.43	0.69	0.72	1.81	1.31	0.92	1.32
4	60.5	33.60	5.83	19.60	0.51	0.54	0.53	0.50	0.54	0.52	0.25	0.50
5	60.4	33.90	5.80	19.60	0.41	0.53	0.49	0.36	0.41	0.39	0.31	1.43
6	60.4	33.90	5.80	19.60	0.28	0.35	0.31	0.27	0.28	0.28	0.13	0.27
7	60.4	33.90	5.80	19.60	0.42	0.54	0.50	0.36	0.42	0.39	0.10	0.45
8	60.4	33.90	5.80	19.60	0.46	0.71	0.54	0.52	0.54	0.53	0.42	1.44
9	60.4	32.00	4.17	17.50	0.52	0.56	0.54	0.43	1.43	0.82	1.22	2.08
10	60.4	32.00	4.17	17.50	0.49	0.53	0.51	0.44	0.49	0.47	0.33	1.59
11	60.4	32.00	4.17	17.50	0.50	0.55	0.53	0.44	0.50	0.47	0.30	1.93
12	60.4	32.00	4.17	17.50	0.47	0.54	0.50	0.43	0.49	0.46	0.31	1.83
13	60.5	31.60	4.13	17.50	0.47	0.98	0.67	0.77	0.93	0.85	0.80	1.97
14	60.5	31.60	4.13	17.50	0.50	0.57	0.53	0.41	0.49	0.45	0.14	0.41
15	60.5	31.60	4.13	17.50	0.38	1.26	0.78	1.32	1.59	1.48	1.16	1.37
16	60.1	31.20	4.27	17.37	0.48	0.98	0.59	0.66	0.97	0.78	0.35	1.34
17	60.1	31.20	4.27	17.37	0.51	0.55	0.54	0.39	0.50	0.45	0.37	1.43
18	60.1	31.20	4.27	17.37	0.52	0.54	0.53	0.46	0.51	0.48	0.18	0.46
19	60.1	31.20	4.27	17.37	0.51	0.55	0.53	0.41	0.51	0.48	0.26	1.32
20	60.2	31.50	4.20	17.43	0.42	1.57	0.79	0.91	1.36	1.04	1.03	1.46
21	60.2	31.50	4.20	17.43	0.50	1.28	0.79	0.92	1.24	1.11	0.98	1.45
22	60.2	31.50	4.20	17.43	0.47	0.90	0.69	0.78	0.89	0.85	0.34	0.83
23	60.3	35.60	3.90	17.10	0.49	1.34	0.77	0.82	1.33	1.01	0.82	2.08
24	60.3	35.60	3.90	17.10	0.37	1.74	1.15	1.37	1.59	1.48	0.68	1.41
25	60.3	35.60	3.90	17.10	0.37	1.61	0.89	0.82	0.88	0.85	0.39	1.13
26	60.3	35.60	3.90	17.10	0.51	0.55	0.53	0.43	0.50	0.46	0.15	0.69
27	60.3	36.00	3.90	17.03	0.39	0.90	0.63	0.60	0.69	0.65	0.21	0.60
28	60.3	36.00	3.90	17.03	0.49	1.39	0.97	0.93	1.00	0.96	0.80	1.14
29	60.3	36.00	3.90	17.03	0.50	0.54	0.52	0.37	0.51	0.47	0.36	1.32
30	60.2	32.40	12.70	25.70	0.54	0.55	0.55	0.43	1.04	0.77	0.70	1.70

Notes. BT = bottom time; TWA = time-weighted average. Dives (1)–(30) were successful evolutions except for: (2) and (7), $PO_2 \leq 0.16$; (4), aborted due to water in rig; (6), aborted due to defective O_2 fuel cell; and (14) and (18), aborted due to closed O_2 bottle. For (26), tabulated minimum PO_2 during ascent reflects a spike that did not persist long enough to warrant dive abort.

Dive	Depth (fsw)	Descent Rate (fsw/min)	BT (min)	Total Dive Time (min)	RB thru Procedure PO_2 MIN (atm)	RB thru Procedure PO_2 MAX (atm)	RB thru Procedure PO_2 TWA (atm)	Preascent Delay PO_2 MIN (atm)	Preascent Delay PO_2 MAX (atm)	Preascent Delay PO_2 TWA (atm)	Ascent PO_2 MIN (atm)	Ascent PO_2 MAX (atm)
31	60.2	32.40	12.70	25.70	0.53	0.55	0.54	0.16	0.53	0.36	0.14	1.31
32	60.2	32.40	12.70	25.70	0.49	0.99	0.67	0.79	1.52	1.10	0.57	1.36
33	60.2	32.40	12.70	25.70	0.47	0.78	0.65	0.70	1.40	1.00	1.14	1.46
34	60.1	32.40	12.63	25.67	0.43	0.80	0.67	0.57	0.86	0.69	0.54	1.62
35	60.1	32.40	12.63	25.67	0.45	1.02	0.72	0.74	1.72	1.05	1.28	1.82
36	60.1	32.40	12.63	25.67	0.52	0.82	0.64	0.67	1.11	0.79	0.69	1.90
37	60.0	32.50	12.70	25.57	0.53	0.55	0.54	0.43	1.07	0.69	0.69	1.75
38	60.0	32.50	12.70	25.57	0.53	0.55	0.54	0.28	0.80	0.49	0.39	1.65
39	60.0	32.50	12.70	25.57	0.51	0.65	0.57	0.52	1.51	0.80	0.44	1.40
40	60.0	32.50	12.70	25.57	0.50	0.67	0.60	0.54	1.19	0.80	0.77	1.34
41	60.0	32.50	12.60	25.57	0.42	1.02	0.76	0.81	1.02	0.91	0.83	1.88
42	60.0	32.50	12.60	25.57	0.47	0.67	0.57	0.45	1.05	0.72	0.43	1.21
43	60.0	32.50	12.60	25.57	0.54	0.56	0.55	0.21	0.54	0.39	0.13	1.68
44	60.0	33.90	13.37	26.60	0.52	0.57	0.55	0.41	1.03	0.65	0.32	1.16
45	60.0	33.90	13.37	26.60	0.49	0.55	0.53	0.10	0.80	0.43	0.28	0.57
46	60.0	33.90	13.37	26.60	0.49	0.55	0.53	0.39	1.21	0.75	0.40	0.96
47	60.0	33.90	13.37	26.60	0.48	0.55	0.52	0.10	0.94	0.44	0.16	1.32
48	60.0	33.50	13.33	26.63	0.50	0.56	0.52	0.56	1.18	0.81	0.84	1.69
49	60.0	33.50	13.33	26.63	0.48	0.53	0.50	0.08	0.92	0.45	0.35	0.70
50	60.0	33.50	13.33	26.63	0.52	0.97	0.69	0.66	1.24	0.88	0.48	1.47
51	59.9	28.70	13.87	26.73	0.65	1.34	0.96	0.89	1.22	1.01	0.90	1.75
52	59.9	28.70	13.87	26.73	0.52	1.13	0.77	0.80	2.00	1.50	0.94	1.85
53	59.9	28.70	13.87	26.73	0.47	0.97	0.69	0.54	1.61	1.20	0.89	1.71
54	59.9	28.70	13.87	26.73	0.48	1.19	0.84	0.80	1.79	1.43	0.92	1.83
55	59.9	27.60	13.87	26.73	0.48	0.52	0.51	0.31	0.90	0.53	0.70	1.46
56	59.9	27.60	13.87	26.73	0.45	0.73	0.60	0.67	1.70	0.84	0.69	1.25
57	59.9	27.60	13.87	26.73	0.48	1.31	0.86	0.94	1.79	1.32	1.02	1.65
58	59.9	32.30	13.13	26.20	0.50	0.56	0.54	0.40	1.14	0.66	0.51	1.59
59	59.9	32.30	13.13	26.20	0.48	0.56	0.53	0.07	0.89	0.51	0.36	0.70
60	59.9	32.30	13.13	26.20	0.47	0.80	0.59	0.49	1.12	0.80	0.54	0.93

Notes. BT = bottom time; TWA = time-weighted average. Dives (31)–(60) were successful evolutions except for: (45), (49), and (59), in which $PO_2 \leq 0.16$. For dives (31), (43), and (47), tabulated values of minimum $PO_2 \leq 0.16$ reflect spikes that did not persist long enough to warrant dive abort.

Dive	Depth (fsw)	Descent Rate (fsw/min)	BT (min)	Total Dive Time (min)	RB thru Procedure PO_2 MIN (atm)	RB thru Procedure PO_2 MAX (atm)	RB thru Procedure PO_2 TWA (atm)	Preascent Delay PO_2 MIN (atm)	Preascent Delay PO_2 MAX (atm)	Preascent Delay PO_2 TWA (atm)	Ascent PO_2 MIN (atm)	Ascent PO_2 MAX (atm)
61	59.9	32.30	13.13	26.20	0.54	1.02	0.80	0.68	0.98	0.79	0.88	1.37
62	60.0	33.20	13.13	26.23	0.38	1.05	0.69	0.48	1.28	0.84	0.83	1.72
63	60.0	33.20	13.13	26.23	0.43	1.06	0.80	0.72	1.16	0.97	0.47	0.99
64	60.0	33.20	13.13	26.23	0.44	1.00	0.66	0.59	0.86	0.69	0.80	1.30
65	60.3	31.70	32.70	45.83	0.44	0.56	0.48	0.46	1.58	1.07	1.04	1.44
66	60.3	31.70	32.70	45.83	0.46	0.49	0.47	0.12	0.85	0.38	0.38	1.54
67	60.3	31.70	32.70	45.83	0.41	1.46	1.03	1.15	1.36	1.24	1.23	1.88
68	60.3	31.70	32.70	45.83	0.40	1.24	0.79	0.86	1.83	1.30	0.96	1.57
69	60.2	31.50	32.77	45.83	0.47	0.50	0.49	0.08	1.45	0.86	0.63	1.28
70	60.2	31.50	32.77	45.83	0.61	1.70	1.27	0.90	1.61	1.08	0.84	1.45
71	60.2	31.50	32.77	45.83	0.48	0.72	0.61	0.55	0.93	0.71	0.66	1.62
72	60.3	34.50	32.63	45.70	0.46	0.49	0.48	0.20	1.16	0.54	0.73	1.65
73	60.3	34.50	32.63	45.70	0.46	0.50	0.49	0.10	0.90	0.39	0.11	1.07
74	60.3	34.50	32.63	45.70	0.40	1.99	1.15	0.86	1.54	1.12	1.05	1.47
75	60.3	34.50	32.63	45.70	0.39	1.15	0.77	0.65	1.22	0.97	0.87	1.41
76	60.3	34.60	32.50	45.70	0.47	0.60	0.54	0.50	0.93	0.79	0.83	1.81
77	60.3	34.60	32.50	45.70	0.51	0.54	0.53	0.34	0.73	0.55	0.25	0.68
78	60.3	34.60	32.50	45.70	0.47	0.51	0.50	0.14	0.75	0.42	0.40	1.20
79	60.2	31.00	32.87	45.83	0.47	0.62	0.55	0.38	1.40	0.69	0.31	0.86
80	60.2	31.00	32.87	45.83	0.44	0.72	0.61	0.42	0.93	0.63	0.90	1.32
81	60.2	31.00	32.87	45.83	0.46	0.93	0.75	0.73	1.85	1.35	0.86	1.72
82	60.2	31.00	32.87	45.83	0.40	0.98	0.73	0.89	1.99	1.34	0.81	1.48
83	60.1	31.20	32.77	45.80	0.47	1.07	0.67	1.01	1.50	1.7	1.05	1.70
84	60.1	31.20	32.77	45.80	0.50	1.06	0.76	0.81	2.13	1.84	0.96	2.05
85	60.1	31.20	32.77	45.80	0.51	0.54	0.53	0.41	1.46	0.94	0.50	1.13
86	59.9	-0.60	14.63	27.70	*	0.00	0.00	0.11	1.20	0.85	0.48	1.16
87	59.9	-0.60	14.63	27.70	*	0.00	0.00	0.09	1.54	1.09	0.96	1.54
88	59.9	-0.60	14.63	27.70	*	0.00	0.00	0.15	1.37	0.74	0.92	1.54
89	59.9	-0.60	14.63	27.70	*	0.00	0.00	0.15	1.05	0.56	0.95	1.25
90	60.2	31.80	33.57	46.63	0.48	0.96	0.78	0.80	1.88	1.54	0.82	1.71
91	60.2	31.80	33.57	46.63	0.49	0.99	0.65	0.44	1.60	0.84	0.83	1.38
92	60.2	31.80	33.57	46.63	0.49	0.63	0.57	0.13	1.21	0.64	0.51	1.20

Notes. BT = bottom time; TWA = time-weighted average. Dives (61)–(92) were successful evolutions except for: (90), in which $PO_2 \geq 1.7$ for 10 minutes; (66), (73), and (78), in which tabulated values of minimum $PO_2 \leq 0.16$ reflect spikes that did not persist long enough to warrant dive abort; and (86), (87), (88), and (89), in each of which real-time data logging failed during RB thru Procedure for approximately 10 minutes.

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